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HOT MIX RECYCLING
1980

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ABSTRACT

1980 saw 400,000 tonnes of specified recycled hot mix pavement placed in Ontario for the Ministry of Transportation and Communications. The recycling was successfully accomplished employing both drum mix and pugmill type asphalt plants.

This paper reports on the overall experience across the Province as well as presenting case studies of three individual recycling contracts.

Test results, observations and conclusions are presented as well as proposed future investigations.

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INTRODUCTION

In 1979, the Ontario Ministry of Transportation and Communications adopted hot-mix recycling as a standard pavement rehabilitation alternative. This decision led to:

(1) the tendering for over 726,000 tonnes of recycled hot mix on 22 contracts in 1979 and 1980.

(2) a Special Provision being placed in all hot mix paving contracts allowing the Contractor the option of incorporating up to 25% reclaimed asphalt in binder course mixes.

The 25% option Special Provision (Appendix I) was intended to encourage the hot mix industry of Ontario generally to become involved in recycling. This Special Provision provides for compensation to the Contractor for the recoverable asphalt cement in the reclaim he adds to the mix. This option was employed on 10 contracts and three other contractors negotiated to recycle on previously awarded contracts.

The recycling contracts were designed so as to provide the greatest economy on a first cost basis. Both full depth and partial depth reclaiming was employed with recycling ratios (reclaimed to virgin) of 40:60 to 70:30. Penetration grade asphalts were chosen as the rejuvenating agent in recycled mixes, incorporating a one grade softer asphalt than would be used for a total virgin mix on the same section of road. A crushed gravel (16 mm Type 'A') was selected to be used as the virgin aggregate for recycling.

Following the decision by the Ministry to commit itself to hot mix recycling, pavement rehabilitation projects for 1980 were critically reviewed and costed to identify the ones where recycling would be cost effective. Twelve projects were intially selected and this expanded to 22 by the end of the 1980 fiscal year.

In 1979 and 1980, ten recycling contracts were completed, recycling 400,000 tonnes of hot mix. Three of these contracts were selected for detailed data gathering and the individual project reports are appended to this paper as case studies.

The three contracts selected were:

Cont. 80-28; Hwy. 29 at Smiths Falls; employing a Barber-Greene K.B. 70 Continuous Mix Plant; recycling at 50:50.

Cont. 79-105; Hwy. 69 at Parry Sound; employing a C.M.I. UDM-1200 Drum Plant; recycling at 70:30.

Cont. 80-202; Hwy. 17 at Warren; employing a Cedarapids 100-32 TMM Drum Plant; recycling at 70:30.

Various data was also gathered from the other recycling contracts and is reported herein.

DESIGN

The typical pavement rehabilitation prior to recycling involved a choice of either resurfacing or pavement removal and replacement using the pulverized reclaimed asphalt as new base material.

With recycling as an alternative design choice, effective treatments are further expanded.

Pavements of structural adequacy that would have normally been resurfaced in the past may now be partial depth reclaimed and recycled, with surplus quantities used for widening and other improvements.

Pavements lacking structural adequacy that would previously be multiple lift resurfaced may now be totally reclaimed and recycled with the virgin aggregates making up the extra material required.

Pavements that would previously be totally removed to correct base problems or to eliminate badly deteriorated pavement may now be totally reclaimed and recycled and surplus reclaim used as improved base material.

The recycle ratio must be selected to best suit the identified needs with the maximum being 70% reclaim material. The following two examples demonstrate the rationale employed in selecting a design.

1. An existing two lane highway has been found to be structurally adequate and by coring the pavement was determined to average 125 mm in thickness. The pavement width is narrow at 6 m and is suffering from wheel track rutting with moderate transverse cracking and multiple longitudinal edge cracking.

   It is desired to widen the pavement to 6.5 m with 0.5 m partial paved shoulders.

The rehabilitation options are:

(a) Resurfacing with a 19 mm sand asphalt (HL-2) levelling course and a 40 mm HL-4 wearing course with the HL-4 being used in the pavement widening.

(b) Milling off 45 mm and using recycled mix at a 70:30 ratio for all the rehabilitation. This will produce a job with balanced quantities at the most cost effective recycle ratio.

Considerations in option (b):

1. Milling off 45 mm assures that the wheel track rutting will be eliminated thus providing a surface true to grade and cross section.

2. Milling less than 45 mm off would require a lower recycle ratio - thus more virgin materials.

3. Recycling at a lower ratio while still removing 45 mm will create a surplus of reclaim material.

2. An existing 6.5 m two lane pavement has been determined to be badly deteriorated and the future AADT is expected to increase significantly. By coring, the pavement was determined to consist of two 40 mm lifts of HL-4 over adequate base and subbase materials. The pavement has severe transverse cracking and a poor ride.

It is desired to rehabilitate this pavement to the same width with added 0.5 m partial paved shoulders.

The rehabilitation options are:

(a) Resurfacing with two lifts of HL-4 to provide a total depth of 160 mm expecting reflection cracking within two years.

(b) Full depth removal to eliminate the badly cracked pavement and recycling at a ratio of 50:50. Recycled mix placed at two 50 mm x 6.5 m binders and one 40 mm x 7.5 m surface will provide for a total pavement thickness of 140 mm and balanced quantities.

The above are presented to demonstrate how recycling can satisfy design needs and are not meant to be definitive.

For example, in case (2), if traffic volumes were high enough to warrant a virgin surface course, the binders could be recycled at a higher ratio so as not to have any reclaim surpluses.

RECLAIMING AND PULVERIZING

Pavement reclaiming was accomplished by three different methods in 1980:

(1) Rip with dozer, load and haul to crusher;
(2) Break out and load with back-hoe and haul to crusher;
(3) Cold plane, load and haul to stockpile.

(1) Six contracts employed the use of a dozer equipped with a ripping tooth to tear the pavement. With this method care must be taken to keep the tip of the tooth just below the bottom of the pavement so as not to unduly disturb the underlying granular material. If the tooth was allowed to penetrate too far under the pavement, the working base for the loading operation and subsequent traffic maintenance would be decompacted. The undue disturbance of the granular base may bring stones to the surface that could be picked up with the pavement. The ripped pavement would usually be further reduced in size by running the dozer over the rubble before loading into trucks with a front end loader. Care must be taken in the loading operation to minimize pick up of the underlying material which has the effect of reducing the recoverable asphalt cement in the pulverized reclaim material. On one contract excessive pickup of the underlying granular reduced the recoverable A.C. in the reclaim from 5.5 in the original pavement to 3.8%.

One contractor employed a Stamler feeder breaker for primary reduction to 100 mm with good success. This machine did not plug up with the larger chunks as a primary jaw has a tendency to do.

On Contract 79-89 in Northwest Region, where the aggregates are of the igneous type, the contractor crushed the reclaim for his binder course at 40 mm and the reclaim for the surface course at 25 mm without any additional degradation of the aggregates. This also eliminated a problem with oversize stones in the recycled mix encountered with the 40 mm product.

The balance of the other five contractors crushed to 40 mm. (See Table I). A problem of oversize stones in the final recycled mix occurred on five of the six contracts crushing to 40 mm. Stones picked up with the

TABLE 1

SUMMARY OF RECYCLING CONTRACTS - 1980

Contract	Hwy.	Design Recycle Ratio	A.C. Grade	% New A.C. Added	Reclaim Reduction	Problem With Oversize	Specified Virgin Aggregate	Actual Virgin Aggregate	Remarks
79-23 Napanee	41	70/30	150/200	1.5	Milled	Yes	16 mm 'A'	HL-4 St. Blending Sa.	Could not obtain mix with 16 mm 'A'
80-28 Smiths Falls	15 & 29	50/50	150/200	2.0	Milled	Yes	16 mm 'A'	HL-4 St. Blending Sa.	Could not obtain mix with 16 mm 'A'
79-105 Parry Sound	69	70/30	300/400	2.0	Crushed 50 mm	Yes	16 mm 'A'	16 mm 'A'	
80-202 Warren	17	70/30	300/400	1.9	Crushed 40 mm	Yes	16 mm 'A'	16 mm 'A'	
80-214 Hearst	11	70/30	300/400	2.0	Milled	Yes	16 mm 'A'	HL-4 St. Blending Sa.	Could not obtain mix with 16 mm 'A'
80-36 Deep River	17	70/30	150/200	2.8	Crushed 40 mm 25 mm	Yes No	16 mm 'A'	16 mm 'A'	Crushing to 25 mm eliminated oversize in final mix.
80-215 Sudbury	69	70/30	150/200	2.0	Crushed 40 mm	Yes	16 mm 'A'	16 mm 'A'	
80-204 Rous Lake	17 & 614	70/30	300/400	2.0	Milled	No	HL-4 Aggregates	HL-4 St. Blending Sa.	Mix cut to 60:40 to satisfy mix design.
79-89 Marathon	17	70/30	300/400	2.3	Crushed 40 mm 25 mm	Yes No	16 mm 'A'	Stone Scalped Sa. Blending Sa.	16 mm 'A' separated and blend Sa. to satisfy mix design.
80-218 Thunder Bay	11 & 17	50/50	150/200	3.0	Crushed 40 mm	Yes	16 mm 'A'	Stone Scalped Sa. Blending Sa.	Contractor's choice of aggregates.
80-220 Red Lake	618	50/50	300/400	2.9	Crushed 40 mm	Yes	16 mm 'A'	Stone Gravel Scr. HL-4 Sa.	Contractor's choice of aggregates.

pavement passing the final product screen would present themselves in the recycled mix whereas the pavement pieces of the same size melt down in mixing.

(2) One contractor (79-105) employed the use of hydraulic back-hoes to break out the pavement and load it onto trucks for transport to the crushers. This operation was quite clean in that very little contamination of the reclaim occurred. This is attributable to the fact that the back-hoe operator can see the interface between the pavement and underlying material.

The pavement chunks were crushed to 50 mm through primary and secondary crushing plants. A problem with oversize stones in the final mix was also encountered on this contract due to no crushed gravel being under the pavement in some areas but only pit run material.

(3) Cold planing was employed on four contracts, (Table I), three of which were partial depth reclaiming and one full depth reclaiming job.

One partial depth reclaiming contract (80-28) employed narrow width planing machines which cut widths of 1.4 and 1.9 metres. With these narrow width machines, two passes are required beside each other to plane a single lane. The planing on this contract was considered less than desirable in that there was often a vertical difference between passes within a lane and the cross-fall between passes was variable. This defeated the intent of the planing being equivalent to placing a levelling course.

On another partial depth reclaiming contract (79-23), oversize stones in the reclaim due to poor stockpiling and handling at the plant site created problems with the paving operation.

The full depth reclaiming contract (80-214) also had problems with oversize stones which were picked up with the pavement both from beneath and from the shoulders.

Only one partial depth reclaiming contract (80-204) was free of the oversize stone problem in the reclaim material.

MIX DESIGN

Until such time as experience should indicate otherwise, the Ministry set its mix design policy to realize the greatest possible savings through the use of the least expensive materials.

(a) The virgin aggregate to be 16 mm type 'A' crushed gravel as opposed to stone and sand.

(b) The softening agent to be one grade softer penetration grade asphalt cement than would be used if a virgin mix was being mixed, as opposed to a proprietary rejuvenating agent.

(c) The highest recycling ratio, up to 70% reclaim, that would meet design and quantity needs.

On the three contracts with partial depth reclaiming, and the one full depth contract, that was accomplished by cold planing machines, the design objectives were not met. This was due to the planing process degrading the aggregates such that the stone content was reduced and the pass 75 µm content increased. The two projects in Eastern Region (79-23 and 80-28) and the one in Northern Region (80-214) required the substitution of HL-4 stone and a blending sand for the 16 mm type 'A' in order to get a high enough V.M.A. to allow for sufficient A.C. in the mix. The one project in Northwestern Region (80-204), employing cold planing, required the substitution of HL-4 stone and a blending sand for the 16 mm type 'A', plus a reduction in the recycling ratio from 70:30 to 60:40 to achieve a satisfactory mix design.

Of the seven recycling contracts, where the reclaim was pulverized by crushing, only one (79-89) was forced to use HL-4 stone and blending sand in lieu of 16 mm type 'A' to get a satisfactory mix design. On two other contracts (80-218 and 80-220) the contractors elected to use separated stone and sand products for his own convenience.

The virgin A.C. added, ranged from a low of 1.5% at a 70:30 recycle ratio to a high of 3.0% at 50:50. The A.C. available from the reclaim material was often lower than expected due to contamination of the reclaim by the underlying gravel on full depth removal contracts.

RECYCLE PRODUCTION

The recycling contractors in 1980 mostly employed the use of drum mixers with one each employing a batch plant and a continuous mix plant. Seven of the eight contracts using drum mixers, on which significant quantities were mixed, recycled at 70:30 and the other at 60:40. The batch and continuous mix plant recycled at 50:50. Drum mixers were also used to recycle on two paving contracts on which the contractors negotiated recycling, one at 70:30 and one at 30:70.

Batch plants were used to recycle on 10 paving contracts where the contractor availed himself of the 25% opion.

The recycle production in 1979-80, our first year of experience, was on the whole quite successful. Mix temperatures of 120°C were easily obtained, and with only one exception (80-214) there were no problems with moisture in the final mix. The one problem common to most of the mixing plants was one of chunks of reclaimed material causing obstruction in the feed system. These chunks of reclaim were usually the result of recementation in the stockpiles but were also from pieces of broken pavement picked up in planing operations. The feeding of the asphalt plant with freshly crushed reclaim was found to eliminate the recementation and thus feed problems at the plant.

The tarping of reclaim piles was not found to be advantageous. The tarps were a considerable logistic problem and it was also found that the reclaim piles would shed rain water rather than absorb it. Moisture in the reclaim was generally in the 1.5 to 2.5% range and presented no particular problem. When the moisture exceeded 4% in the reclaim on Contract 80-28 (Continuous Mix Plant), the recycle ratio had to be lowered from 50:50 to 45:55 to get satisfactory discharge temperatures.

On Contract 79-105, two trials were conducted using Chevron Asphalt Ltd. RA 5.2 emulsion in place of the asphalt cement. These trials proved successful and the mix was not appreciably different from the regular recycled mix. See case study Appendix II.

TESTING OF RECYCLED MIX

The testing of mix produced on the recycling contracts was performed by at least two, and up to four separate laboratories in the case of the contracts subjected to the in depth study.

1. On each contract a field laboratory would be located at the plant site for process control. This laboratory would perform such tests as:

   (a) extraction tests on reclaim,
   (b) moisture content of aggregates,
   (c) extraction tests on recycled mix.

2. Regional mobile mix design laboratories would visit a contract and perform:

(a) plant checks (determined Marshall values of mix),
(b) check compaction through coring.

3. Regional central laboratories performed:

(a) plant checks on duplicate samples tested in the field,
(b) Northwest Region only, also performed penetration and viscosity tests on the recovered asphalt.

4. Downsview central laboratory performed:

(a) penetration and viscosity tests on the recovered asphalt,
(b) resilient modulus testing.

Table 2 compares the design values for asphalt cement and stone content to the actual values obtained by extraction.

TABLE 2

MEAN MIX CONFORMITY TO DESIGN

Contract No.	Design		Regional Laboratory Mean Extraction Results	
	A. C.	+4.75 mm	A. C.	+4.75 mm
80-218	5.5	35	5.2 (-0.3)	32 (-3)
79-89	5.1	40	5.1	41 (+1)
80-204	5.1	40	5.1	37 (-3)
80-214	5.0	35	4.9 (-0.1)	36 (+1)
80-215	4.8	38	5.1 (+0.3)	37 (-1)
80-202	4.6	40	4.7 (+0.1)	34 (-6)
79-105	5.0	40	5.2 (+0.2)	36 (-4)
80-36	5.0	43	5.0	44 (+1)
79-23	5.0	41.5	4.9 (-0.1)	37 (-4)
80-28	4.7	40.5	4.8 (+0.1)	45.5 (+5)

On the average the mean asphalt cement content of the recycled mixes came very close to the design. The variability about the mean asphalt content was high with a pooled mean standard deviation of 0.3 for 10 contracts (see Table 3). This means that with 95% confidence the mix will vary ± 0.6% either side of the mean. This variation is twice that allowed in the specifications. On five of these same contracts a total virgin mix was produced and the mean pooled standard deviation for them was lower at 0.23. It is interesting to note that not one contract stayed within the specification limits for A.C. content even when producing a virgin mix.

In looking at the A.C. variation according to type of drum mix plant (see Table 4), we see a trend for one plant type to maintain better control over the A.C. content than the other. With only four contracts employing each type, no conclusions should be drawn; but it raises the qeustion as to whether the system for adding A.C. to the mix is superior in one plant type.

The mean stone content (+ 4.75 mm) of the recycled mixes was often less than the mix design. Four contracts had mean stone contents that were 4% or more away from the desired mix. The mix on one contract only, met the specification requirement for variability on the 4.75 mm for surface course pavement and the mix on one more met the requirement for binder courses (see Tables 2 & 3). M.T.C. Form 310 allows 5% and 7% variation from design on the 4.75 mm for surface and binder courses respectively. On two of the five contracts that produced a totally virgin mix, the sand/stone split was more variable with the virgin mix than with the recycled. It would seem fair to say after reviewing the data, that the gradation control on recycled mixes compares closely to that of virgin mixes.

The plant check results do not distinguish the recycled mixes as being much different from virgin HL-4 mixes except for slightly higher stabilities and flow values. Table 5 summarizes the Marshall values obtained on each contract by both the Regional and Mobile laboratories.

Penetrations of the recovered asphalt from six out of the eight contracts that were tested, yielded lower penetrations than would have been expected from a virgin mix.

The minimum penetration required is based on 60% of the lowest penetration of the grade of A.C. that would be used in a virgin mix on the same project, i.e. 60% of 150-200 = 90. This 60% is considered the extreme amount of hardening to be expected in the mixing, hauling and laying of a hot mix pavement. As we can see in Table 6, this extreme has been greatly exceeded on three contracts and this justifies concern for the durability of these pavements.

TABLE 3

SUMMARY OF MIX VARIATION

	VIRGIN MIX				RECYCLED MIX			
	A. C.		Pass 4.75		A. C.		Pass 4.75	
	n	σ	n	σ	n	σ	n	σ
80-218 Thunder Bay	33	0.16	33	2.27	29	0.19	29	4.42
79-89 Marathon	38	0.18	38	2.95	131	0.24	131	3.90
80-204 Rous Lake					73	0.20	72	2.75
80-214 Hearst					70	0.50	70	2.48
80-215 Sudbury					78	0.35	79	2.67
80-202 Warren	20	0.27	20	5.16	36	0.28	35	2.86
79-105 Parry Sound	23	0.27	23	3.14	151	0.31	151	2.80
80-36 Deep River	36	0.27	35	3.66	74	0.47	73	4.47
79-23 Napanee					62	0.27	62	3.73
80-28 Smiths Falls					68	0.33	68	3.07

Note: These entries are the pooled mean standard deviation of all laboratories reporting on a contract.

TABLE 4

A.C. VARIATION BY PLANT TYPE

Drum Mix Plant Type "A"			Drum Mix Plant Type "B"		
Cont.	n	σ	Cont.	n	σ
79-89	131	0.24	80-204	73	0.20
80-215	78	0.35	80-214	70	0.50
80-202	36	0.28	79-105	151	0.31
79-23	62	0.27	80-36	74	0.47
Pooled Mean		0.28			0.37

TABLE 5

RECYCLING SUMMARY OF MARSHALL VALUES

			A.C.	SA.	VOIDS	FLOW	STAB.	V.M.A.	% PASS 200 IN SAND	B.S.G.	M.S.G.
80-220 Red Lake	Reg.Lab. n = 11	X	5.0	55.0	2.7	10.8	3459	14.9	8.23	2.428	2.495
		σ	0.24	2.70	0.45	2.16	309	0.51	0.64	0.008	0.013
80-218 Thunder Bay	Reg.Lab. n = 9	X	5.3	69.4	4.6	8.4	2906	17.2	4.93	2.4368	2.5539
		σ	0.17	2.49	1.01	0.65	335	0.90	1.05	0.021	0.007
	Mob.Lab. n = 25	X	5.1	62.0	2.6	8.8	3047	14.8	5.49	2.4738	2.5664
		σ	0.17	3.00	0.72	0.96	376	0.78	1.22	0.019	0.008
79-89 Marathon	Reg.Lab. n = 25	X	5.1	58.7	2.5	12.9	3564	14.5	8.04	2.420	2.498
		σ	0.18	3.94	0.83	1.12	792	0.69	0.33	0.017	0.009
	Mob.Lab. n = 46	X	5.1	60.1	3.6	8.3	2853	15.8	5.81	2.407	2.476
		σ	0.21	4.18	0.99	0.97	484	0.78	1.15	0.258	0.069
80-204 Rous Lake	Reg.Lab. n = 7	X	4.9	61.9	4.2	9.1	2767	15.6	8.11	2.389	2.498
		σ	0.32	3.02	0.96	0.93	709	0.84	0.31	0.013	0.0131
	Mob.Lab. n = 28	X	5.1	63.3	3.1	8.8	3077	15.4	5.77	2.402	2.4921
		σ	0.15	1.75	0.71	1.18	438	0.69	0.95	0.018	0.010
80-214 Hearst	Reg.Lab. n = 24	X	4.9	64.0	4.0	10.5	2639	15.6	6.60	2.372	2.488
		σ	0.44	1.97	1.72	1.09	404	0.84	0.77	0.027	0.020
	Mob.Lab. n = 5	X	4.9	61.2	3.9	12.7	3244	15.6	8.34	2.397	2.495
		σ	0.45	2.46	0.90	0.73	222	0.45	0.39	0.014	0.015
80-215 Sudbury	Reg.Lab. n = 17	X	5.1	63.4	2.8	13.1	3336	15.4	7.68	2.475	2.545
		σ	0.39	2.07	0.83	1.48	425	0.36	0.45	0.013	0.016
	Mob.Lab. n = 9	X	4.7	63.6	2.4	14.8	3849	14.1	7.21	2.480	2.540
		σ	0.28	2.28	0.95	1.55	277	0.41	1.04	0.013	.012
80-202 Warren	Reg.Lab. n = 10	X	4.7	66.3	3.5	13.6	3324	15.1	8.18	2.470	2.559
		σ	0.31	2.83	0.85	0.82	294	0.20	0.24	0.012	0.012
	Mob.Lab. n = 5	X	5.1	66.0	2.4	15.1	3946	15.2	7.38	2.498	2.559
		σ	0.17	0.99	0.16	1.27	344	0.35	0.99	0.006	0.009
79-105 Parry Sound	Reg.Lab. n = 45	X	5.2	63.9	2.4	13.5	3316	15.3	9.5	2.475	2.535
		σ	0.21	2.24	0.39	1.86	322	0.55	0.88	0.01	0.01
	Mob.Lab. n = 21	X	5.7	61.7	1.9	13.4	3370	16.0	9.3	2.480	2.529
		σ	0.45	1.74	0.51	1.61	335	0.84	1.78	0.01	0.02
80-36 Deep River	Reg.Lab. n = 14	X	5.0	56.4	2.8	13.7	3992	14.9	10.6	2.413	2.484
			0.37	4.96	0.54	1.01	379	0.69	0.52	0.007	0.013
	Mob.Lab. n = 5	X	5.1	56.2	3.4	12.3	3460	15.5	9.3	2.400	2.485
			0.24	5.50	0.53	0.61	355	0.86	0.37	0.013	0.003
79-23 Napanee	Reg.Lab. n = 29	X	4.9	63.5	2.4	17.5	3046	14.3	8.3	2.445	2.505
			0.25	3.00	0.61	1.44	271	0.64	0.98	0.013	0.008
	Mob.Lab. n = 5	X	5.32	58.2	1.7	20.8	2822	15.4	7.7	2.464	2.507
80-28 Smiths Falls	Reg.Lab. n =	X									
	Mob.Lab. n = 20	X	4.9	54.3	1.9	13.7	3251	14.1	8.4		
			0.29	2.98	0.55	1.68	478	0.58	1.13		

TABLE 6

ACHIEVED PENETRATIONS

Contract		Recycled Ratio	Pen. Achieved	Min.Pen. Required	% of Desired
79-89	Marathon	70:30	66*	90	73
80-204	Rous Lake	60:40	80*	90	88
80-218	Thunder Bay	50:50	48*	90	53
80-202	Warren	70:30	39*	52	75
79-105	Parry Sound	70:30+	62	52	119
80-36	Deep River	70:30	57	52	110
79-23	Napanee	70:30	47*	52	90
80-28	Smiths Falls	50:50	46*	52	88

* Lower than desirable penetration.
\+ Used two grades softer A.C. instead of one.

TABLE 7

RECYCLING PENETRATION SUMMARY

Contract	Recycle Ratio	PENETRATION OF A.C. IN:				
		Original Pavement	Reclaim	New A.C.	Recycle	Math. Prediction
79-89	70:30	41	34	290	66	97
80-204	60:40		63	284	80	106
80-218	50:50	33	32	190	48	80
79-105	70:30	23	33	341	61	102
80-36	70:30		34	169	57	64
80-202	70:30	30	24	347	39	112
79-23	70:30	23	23	149	47	43
80-28	50:50	27	30	124	46	49

Note: These numbers represent the means of all samples. Original pavement samples are as few as 1 and should not be credited with much reliability.

The viscosity of the recovered asphalts as summarized in Table 8 relates as expected to the penetrations presented in Table 7, in that the highest and lowest viscosity correspond to the lowest and highest penetrations respectively.

TABLE 8

RECYCLING VISCOSITY SUMMARY

Contract	Recycle Ratio	Viscosity of A.C. in:			
		Original Pavement	Reclaim	A.C.	Recycle
79-89 Marathon	70:30	958	894	161	443
80-204 Rous Lake	60:40		420	163	340
80-218 Thunder Bay	50:50	828	954	210	635
79-105 Parry Sound	70:30		793	148	426
80-36 Deep River	70:30		719	230	461
80-202 Warren	70:30	895	971	140	621
79-23 Napanee	70:30	969	885	231	498
80-28 Smiths Falls	50:50	918	859	245	545

Note: These numbers represent the means of all samples. Original pavement samples are as few as 1 and should not be credited with much reliability.

Compaction was found to closely compare to that obtained on virgin mixes. The average compaction was found to be 95% of 75 blow Marshall.

Briquettes of recycled mix were made up on several contracts and sent to the Downsview laboratory for resilient modulus testing. The testing is just now underway and the results of this work are, as yet, not available.

PAVING

The recycled mixes were not found to handle very much differently than virgin mixes through the pavers. As with any hot mix pavement, there are variations in handling characteristics from job to job. Problems with hand work, i.e. shovelling and raking, were the most often raised objections with the recycled mixes. Typical complaints were that the mixes were sticky, harsh, stiff or dead. Not all recycled mixes exhibited these handling problems.

By far the most common problem observed was that of oversize stones in the mix which would drag under the paver screed and tear the mat. Occasionally the screed would have to be raised to clear a stone, resulting in a bump in the finished pavement. On two contracts (80-214 and 80-28) it was reported that lumps of reclaimed pavement which did not melt down in the recycling operation, presented problems at the paver.

Recycled hot mix was found to be "bulkier" than virgin mixes necessitating the placing of a thicker mat to achieve the desired compacted thickness. This is likely a result of the screed not compacting these more stable mixes as much as a virgin mix.

The recycled mixes were observed to be very stable under rolling with little tendency for mat creep. These mixes cooled and set up much quicker than virgin mixes necessitating that the rollers keep close to the pavers.

The Mays Ride Meter was employed to determine the riding characteristics of the recycle projects. It was found that the mean inches per mile (ipm) of roughness for all recycling contracts was 71 ipm. This compares well with the ride achieved on both 1 and 2 lift resurfacing contracts in 1980 with means of 72 and 69 ipm respectively. Individual data is presented in Table 9.

TABLE 9

ROUGHNESS MEASUREMENTS ON
RECYCLING CONTRACTS

Cont.	Hwy.	IPM
80-218 Thunder Bay	11 & 17	86 NB 84 SB
79-89 Marathon	17	75 EB 76 WB
80-204 Rous Lake	17	64 EB 68 WB
80-214 Hearst	11	64 EB 67 WB
80-202 Warren	17	54 EB 52 WB
79-105 Parry Sound	69	65 NB 71 SB
80-36 Deep River	17	55 WB 54 EB
79-23 Napanee	41	78 NB 84 SB
80-28 Smiths Falls	29	83 SB 90 NB

OBSERVATIONS/CONCLUSIONS

- The reclaiming and pulverization by cold planing reduces the stone content and increases the pass 75 µm content of the reclaimed pavement significantly.

- Oversize pieces of pavement can be picked up in the reclaiming operation even with partial depth planing due to breakout of cracked pavement.

- Contamination of partial depth planed reclaim, by stones, can occur due to poor stockpiling and handling practices.

- Contamination of full depth planed reclaim can occur due to pickup of underlying gravel and shoulder materials.

- Planed reclaim yields a higher percent of A.C. due to lower contamination as compared to a rip, haul and crush, reclaim operation.

- Pavement removal by backhoe reduces the contamination as compared to ripping with a dozer and loading with a front end loader.

- Crushing to 25 mm does not appear to degrade the aggregates in reclaim composed of igneous materials.

- Pulverized reclaim recements in the stockpile if piled too high or stored too long.

- The tarping of stockpiles should be left to the contractor's discretion.

- Mix designs using 16 mm type "A" crushed gravel were not achieved with planed reclaim.

- Blending sand and 16 mm Type 'A' separated into stone and screenings was required to achieve a mix design on one out of seven contracts pulverizing the reclaim by crushing.

- H.L. - Stone and sand should probably be specified for recycling to allow gradation correction of the mix no matter what reclaiming process is used.

- Lower recycle ratios should be considered to improve mix characteristics and allow the use of a higher percent of virgin asphalt to soften excessively hard A.C. in the reclaim.

- Pugmill plants, both batch and continuous mix, are capable of recycling at 50:50 ratios.

- Drum mixers are capable of recycling at ratios up to 70:30.

- Oversize in the reclaim, both pavement chunks or stones, was a common problem at the cold feed on recycling contracts.

- Production of recycled mix from freshly produced pulverized reclaimed pavement will minimize plant cold feed problems.

- Desired mix temperatures were easily obtained with recycled mixes.

- Moisture in the final product was only a problem on one contract.

- Emulsions may be used as a recycling agent through a drum mix plant.

- Excessive hardening of the asphalt cement has occurred on most recycling contracts.

- Higher Marshall stabilities and flow values were achieved with recycled mix.

- Appropriate action will be required to achieve better mix control of recycled mixes.

- Machine placing of recycled mix is equal to that of virgin mixes.

- Hand work with recycled mix can be expected to be more difficult than with a virgin mix.

- Compaction of recycled mix is comparable to that of a virgin mix.

- In place recycled mix looks the same as a virgin mix.

FURTHER INVESTIGATIONS REQUIRED

Asphalt Cement Penetrations:

In reviewing the data assembled, there is an indication that the pulverizing of the old pavement further hardens the asphalt cement. This was not expected and the limited data so far would not allow for a conclusion either way.

The penetration of the recovered asphalt cement on most recycling contracts so far has been much lower than expected. Based on previous experience this will lead to premature cracking of the pavement. Although the performance of recycled pavements in Ontario is something only the future will determine, it is felt that a higher penetration is most desirable. Loss of penetration or hardening of the asphalt may be due to:

- burning of the virgin A.C. in the mixing process,
- refiners adding back solvents to harder base asphalts which flash off in the mixing process.

Work in 1981 will be directed at identifying the cause or causes of the excessive hardening and determining remedial action.

Oversize:

In 1980, oversize materials were a problem in two areas:

(i) In the reclaim cold feed to the asphalt plant, (usually lumps or recemented chunks of pavement).

(ii) In the final recycled mix at the paver, (usually stones that passed the final product screen in the crushing operation).

The oversize problem at the reclaim cold feed can be greatly influenced by the contractor's equipment and handling operations. The knowledge and experience gained in 1980 by the industry should mostly eliminate this nuisance.

As the purchaser of the final product, the Ministry is most concerned with the oversize in the final product. On two projects, the contractors had problems with stones in the final mix when crushing reclaim to 40 mm, upon crushing to 25 mm eliminated the problem. On one of these two jobs extractions proved no further degradation of the aggregates occurred in the finer crushing.

Work in 1981 will be directed at identifying the amount of degradation of aggregates in the reclaiming and pulverizing operation on all recycling contracts.

APPENDIX I

SPECIAL PROVISION

RECYCLED HOT MIX

Subsection 310.03.01 of Form 310 is amended by the addition of the following:

For all binder course pavements, up to and including 25% of the composition of the mixture may be reclaimed asphaltic concrete. Where the Contractor proposes to use a mixture containing more than 25% reclaimed asphaltic concrete he shall request permission to do so by detailing his proposals, in writing, including the type of asphaltic concrete mix and the penetration grade of the asphalt cement he proposes to use. The Contractor shall not proceed with his proposal until he has received the Engineer's permission in writing.

Where the Ministry supplies the asphalt cement and the Contractor supplies the asphaltic concrete:

(a) which he obtained from sources other than this contract, or

(b) where the contract stipulates the Contractor is responsible for the disposal of the asphaltic concrete removed from the job,

the Contractor will be reimbursed for the amount of asphalt cement provided in the reclaimed asphaltic concrete by payment at the Ministry's purchase price established for the asphalt cement supplied for the balance of the mixture at the time the reclaimed material is incorporated in the mixture. The asphalt cement content in the reclaimed asphaltic concrete will be determined by the Ministry testing procedures.

APPENDIX I-2

REQUIREMENTS FOR 16 mm TYPE "A"

Gradation Limits for 16 mm Crushed Virgin Aggregate

Sieve Designation	Percentage Passing
16.0 mm	100
13.2 mm	75-95
9.5 mm	50-80
4.75 mm	25-50
1.18 mm	10-40
300 µm	2-20
150 µm	0-10
75 µm	0-5

Quality Requirements for 16 mm Crushed Virgin Aggregate

Physical Test	Requirements
Los Angeles Abrasion Grades 'B', 'C', 'D' Loss MTC Test LS-603	35 (% Maximum)
Petrographic Number MTC Test LS-609	160 (Maximum)
Percent Crushed MTC Test LS-607	60 (% Minimum)

This material may come from either gravel pits or quarries, and the quality requirements are the same as those specified for standard hot-mix aggregates. The decision to specify a single product aggregate rather than separated stone and sand was based on the fact that this is the most economical aggregate generally available.

APPENDIX II

CASE STUDY CONT. 79-105
C.M.I. DRUM MIXER AT 70:30

CONTENTS

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RECYCLING CONTRACT 79-105; HWY. 69; FOOT'S BAY TO PARRY SOUND

GENERAL BACKGROUND

This highway carries heavy commercial traffic throughout the year; being the shortest route from southern Ontario to the north-central and north-western areas of the province. In the summer it also carries a high percentage of recreational traffic which results in long queues with little opportunity to pass in the opposing lane. In 1979, this section of the highway was determined to be carrying 5200 to 5900 average daily traffic.

The project was originally designed to continue northward, 2.7 metre paved shoulders another 20.1 km to the junction of Hwy. 141 from the two previous contracts constructed in 1976. The old pavement was to be pulverized and used as a granular base for a new pavement.

This design was subsequently changed to recycling in order to make maximum use of the old pavement. In addition, another 18.0 km from Hwy. 141 to Parry Sound was added to the project using recycled pavement for shoulder paving.

THE EXISTING PAVEMENT

The highway cross-section generally consisted of 7.3 m wide pavement with 2.4 m granular shoulders. The pavement depths were determined to be quite variable from 89 to 280 mm with an average thickness of 160 mm. The pavement was rated as having a good ride with intermittent moderate wheel track rutting and moderate transverse and longitudinal cracking.

NEW PAVEMENT DESIGN

The existing pavement in the south 20.1 km was to be totally removed and pulverized and stockpiled for recycling. The only pavement removal in the north 18 km was for frost heave treatment or other localized works. The new pavement on the south half of the project was to have the shoulders and the binder courses of the main lanes constructed of recycled asphalt composed of 70% reclaim and 30% virgin materials. The main lanes were to be surfaced with a total virgin HL-4 mix. The north half of the project was to have the shoulders paved using recycled pavement as above. Pavement cross sections are contained in Appendix I.

PAVEMENT RECLAIMING

The contractor elected to remove the old pavement with two Hitachi UH14 backhoes equipped with 1.3 m^3 buckets. The backhoes were spaced 150 to 300 metres apart, each removing one lane of the pavement. This allowed single lane traffic maintenance controlled by flag personnel between the two operations. The backhoes worked alone in lifting up and breaking the pavement into suitable size and loading the trucks. This removal operation was found to produce very little contamination from the underlying granular material. Each machine removed approximately 1670 m^2 per day or 617 tonnes based on an average thickness of 152 mm. The trucks hauled the broken pavement to a wayside pit located near the centre of the contract where it was stockpiled. Located in the pit were Cedarapids primary and secondary crushing plants and a C.M.I. UDM 1200 drum mix plant equipped for recycling. It was soon evident that the pit was too confined for the scale of operation being conducted. Reclaim crushing operations had to be shut down at times because of the limited space. The virgin 16 mm Type 'A' aggregate was imported to the pit and stockpiled next to the mixing plant and the crushed reclaim was also stockpiled next to the plant. The reclaim pavement from the road being stockpiled for feed to the crushers threatened to choke off the pit access. The contractor reduced the reclaimed pavement to minus 50 mm and thus any stones picked up with the pavement at the road also were only reduced to this size. The stones picked up with the pavement were not due to excessive excavation by the backhoes but due to there not being crushed gravel beneath the pavement in some locations.

TESTING OF RECLAIM

Prior to reclaiming operations, pavement cores were extracted and the percent asphalt cement determined. These cores revealed a large variety of mixes and depths with an average asphalt cement content in a range about 5.8%. This data was not suitable for mix design purposes since any full depth reclaiming operation is, of necessity, going to include some granular base material, which has the effect of lowering the asphalt cement content. Once the contractor started crushing the old pavement, samples were obtained and extracted for mix design purposes. These original production samples were determined to have a mean asphalt cement content of 4.25% on which the mix design for recycled mix was based.

Twice daily moisture checks were made on the reclaim and virgin aggregate stockpiles from the area from which the plant feed was being obtained. This data was used to set the controls of the drum mix plant which subtracts the moisture from the weight of aggregate going over the Ramsey scales. See Appendix II "Daily Summary of Conditions at Plant".

During the first month and one half of recycle mix production, daily samples of reclaim were obtained from the cold feed of the hot mix plant. These samples were built up over the day's work by randomly obtaining a small portion at a time until about 20 kg were collected. This sample would then be thoroughly mixed and split down using a splitter box until two samples of about 3 kg remained. One of these samples was then extracted in the field laboratory and the other shipped to the Downsview Central Laboratory for Abson recovering testing. See Appendix III.

SUMMARY OF TESTS

Field Lab.	-	Moisture	$\bar{x}$	1.5%
			R	2.4
			σ	0.46
			n	45
	-	A.C.	$\bar{x}$	4.57%
			R	1.11
			σ	0.37
			n	23
Central Lab.	-	A.C.	$\bar{x}$	4.42%
			R	1.13
			σ	0.33
			n	18
		Pass #4	$\bar{x}$	67.9%
			σ	3.0
			n	18
		Pass #200	$\bar{x}$	5.21%
			σ	0.5
			n	18
		Pen.	$\bar{x}$	33.2
			σ	5.5
			n	25
		Visc.	$\bar{x}$	792.9
			σ	167.3
			n	25

One could well expect the extraction results to be very uniform due to the averaging effect of the sampling method, but such is not the case. Both laboratories identified a wide range of asphalt cement contents. In the daily samples, 1.11 and 1.13% were established by the field and Central laboratories respectively. This strongly suggests that the variation from time to time would be even higher.

The data obtained shows that at a 70:30 recycle ratio, the final mix could be expected to range .78% in A.C. content due to the influence of the reclaim alone.

With an asphalt penetration of 33 in the old pavement and knowledge of the penetration of the virgin asphalt cement, a mathematical exercise may be carried out to predict the final in pavement penetration of the recycled mix. Certain basic assumptions of course have to be made in order to conduct this exercise, namely:

1. The old asphalt cement, since it now is in the 30s pen. range, will not harden any more.

2. The virgin asphalt cement will have a penetration drop of 40% of original.

Old A.C. @ Pen. 33 is 3/5 of mix (60%)
New A.C. @ Pen. 341 is 2/5 of mix (40%)
(.60 x 33) + (.40 (341 x .60)) = 102

Predicted in pavement A.C. pen. is 102.

MIX DESIGN

Samples of the crushed reclaimed pavement and crushed 16 mm Type 'A' gravel were sent to the North Bay Regional Laboratory for a mix design.

It was determined that with an addition of 2.0% 300/400 pen. A.C., a design composed of 70% reclaim and 30% 16 mm Type 'A' would yield a mix with a stone/sand split of 43-57 with a total A.C. content of 5.0%. Other values of the mix that were determined were:

Voids - 2.1% +
Flow - 13.2 ±
Stability - 2600

RECYCLE PRODUCTION

The Contractor employed a C.M.I. UDM 1200 drum mixer rated at 272 tonne per hour capacity to produce the recycle mix. The reclaim material entered the drum at a centre collar, fed from a single cold feed bin equipped with an inclined grizzly. The virgin aggregate was fed to the burner end of the drum from a standard three bin cold feed.

The contractor operated the plant near rated capacity for much of the work with an average hourly rate of 255 tonne/hr over the first month and a half. This high production rate was permitted by the relatively low moisture content of both the reclaim and virgin aggregates, 1.5 and 2.1% average respectively. See Appendix II, "Daily Summary of Conditions at Plant". The mix was produced with an average drum discharge temperature of 123°C before going up a drag flight conveyor to a surge silo. Mix control was found to be less than satisfactory with the A.C. content being on the average high and quite variable throughout production and the sand/stone split highly variable the first two weeks. In an effort to lower the asphalt cement content the A.C. set point on the plant was lowered from the desired 2% in increments over several days to a low of 1.5% at one point. This was found to be low and most of the mix was then produced with the plant set for 1.8% A.C. The high variability of the asphalt cement content can be related to the variability in the reclaim but this does not explain the overall high mean A.C. content of the final mix.

At one point gobs of sand and asphalt were noticed in the mix and a modification to the drum flighting eliminated the problem.

One trial tanker load of 150/200 pen. A.C. was substituted for the 300/400 pen. and no noticeable changes were observed with mixing or handling.

Two separate trials of one tanker load each were made using an emulsion in place of asphalt cement. The first trial had the mix placed in the binder courses and the second had the mix placed on the surface in the shoulders. The emulsion called RA-5.2 was specifically formulated as a recycling agent by Chevron Asphalt Limited. These mixes were produced at a lower discharge temperature, 115 to 118°C and a lower production rate 218 to 222 tonne/hr. The amount of emulsion added to the mix was increased over the amount of A.C. that would normally be added to compensate for the water in the emulsion. No problems were encountered in the production of the emulsion mix.

TESTING OF RECYCLED MIX

Testing of the recycled mix was accomplished by several laboratories over the course of the work.

1. FIELD LABORATORY: Located in the same pit with the mixing plant, did the routine daily extraction tests for mix control as well as moisture determinations of the reclaim and virgin aggregates as well as the final mix.

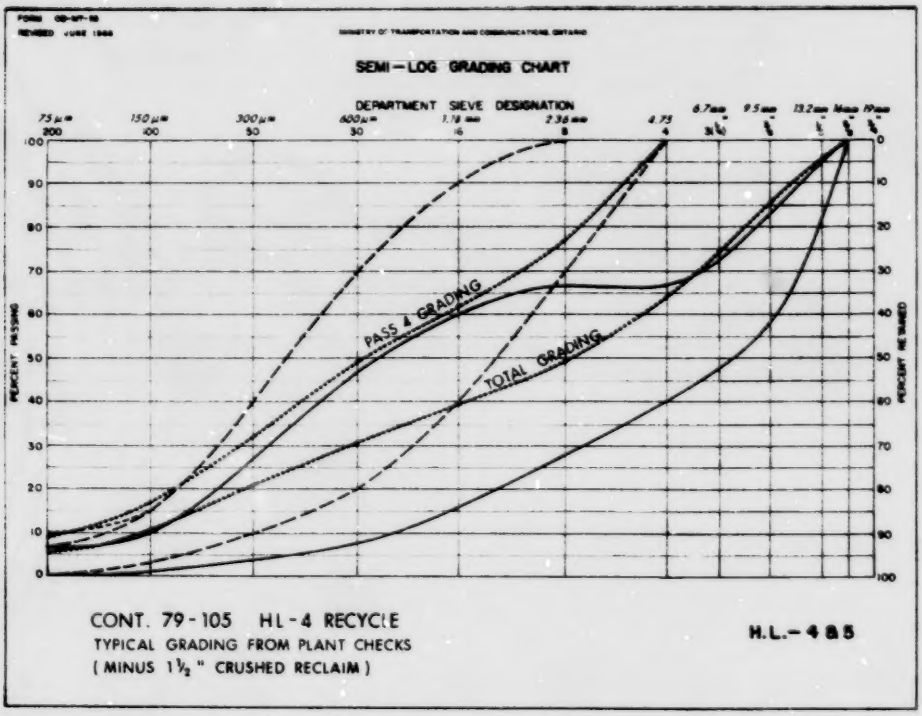
2. MOBILE LABORATORY: Periodic visits to site to perform Marshall value tests on mix and to cut cores for compaction determination.

3. NORTH BAY REGIONAL LABORATORY: Performed the plant checks which determine the gradation and A.C. content as well as Marshall values of duplicate samples tested in the field laboratory.

4. DOWNSVIEW CENTRAL LABORATORY: Performed Abson Recovery testing of duplicate samples tested in the field. Cores of in situ pavement were obtained and tested for compaction and Marshall values.

Summaries of laboratory results are contained in Appendix IV.

GRADING OF RECYCLED MIX



SUMMARY OF TEST RESULTS

	A. C.	% Pass #4	Voids	Flow	Stab.	V.M.A.	% Pass 200 in Sand
Field Lab.							
Mean of 74	5.52	63.1					
Mobile Lab.							
Mean of 11 (visit 1)	5.50	63.5	2.4	10.4	2937	15.9	7.3
Mean of 21 (visit 2)	5.66	61.7	1.9	13.4	3370	16.0	9.3
Regional Lab.							
Mean of 45	5.23	63.9	2.4	13.5	3316	15.3	9.5
Downsview Lab.							
Mean of 10 Plate	5.15	62.7					5.9
Mean of 5 Cores	5.01	62.2	2.5	13.9	4443	14.4	6.1

Abson Recoveries:	Pen.	Visc.
Mean of 23 Plate Samples	61.2	425.5

Percent Compaction: (95 Blow Marshall)

Mobile Lab.
Mean of 10 — 95.2%

Downsview Lab.
Mean of 5 — 94.6%

Moisture in the final mix was determined to average 0.11%.

The asphalt cement content of the mix could be expected to vary at least 0.78% due to the influence of the reclaim. The three laboratories conducting the most testing determined the following ranges:

Field Lab.	1.60%
Mobile Lab.	1.53%
Regional Lab.	0.87%

It is interesting to note that the two laboratories having the highest range also reported the highest mean A.C. content. These two laboratories obtained fresh mix from behind the paver for immediate testing and the Regional samples were 2 to 18 with an average of 7 days old when tested. The field laboratory determined the moisture content of the final mix to be 0.1% or less, with only one exception; so a drying of the sample with time seems unlikely to be the causative factor. The Downsview laboratory, which tested samples a month or more after sampling, recorded the lowest mean A.C. content.

The gradation variation is actually less on the recycled mix than with the total virgin mix used in the surface course on this contract. The variation of the stone sand split of the recycled mix determined by the field laboratory is slightly greater than that reported for drum mixers in 1978 by J. Loughnan (EM #18) and far worse than conventional plants not using silos.

Loughnan also reported less hardening of the asphalt cement with drum mixers as opposed to batch plants. It is surprising indeed that the final penetration of this recycled mix (61) is so much lower than the mathematical prediction (102) discussed previously under testing of reclaim.

The mean Marshall values of the recycled mix are acceptable with the exception of stability. The abnormally high stabilities, particularly the ones determined from pavement cores, may be an indicator of a brittle pavement subject to thermal cracking.

The trial batches using RA-5.2 emulsion have no Marshall values to distinguish them from the regular recycled mix.

The compaction testing conducted by both the Mobile laboratories and the Downsview laboratory determined the range of compaction to be from 92 to 98% with a mean of 95%. These results are typical of compaction achieved on most of M.T.C. paving contracts.

PAVING

The pavement was placed using Blaw Knox spreaders followed by Dynapac dual drum vibratory and pneumatic tire rollers.

The placing of the first binder was often held up due to a lack of prepared grade. Frequent rain and heavy traffic made grade maintenance ahead of paving a difficult task. Many small areas of the first binder broke up and required patching due to soft grade.

The first binder on grade was placed at 76 mm instead of 64 mm in order to get proper distribution quantities. At this depth, the recycled mix had a tendency to push out laterally under the vibratory rollers and the rollers would leave a bump wherever they stopped.

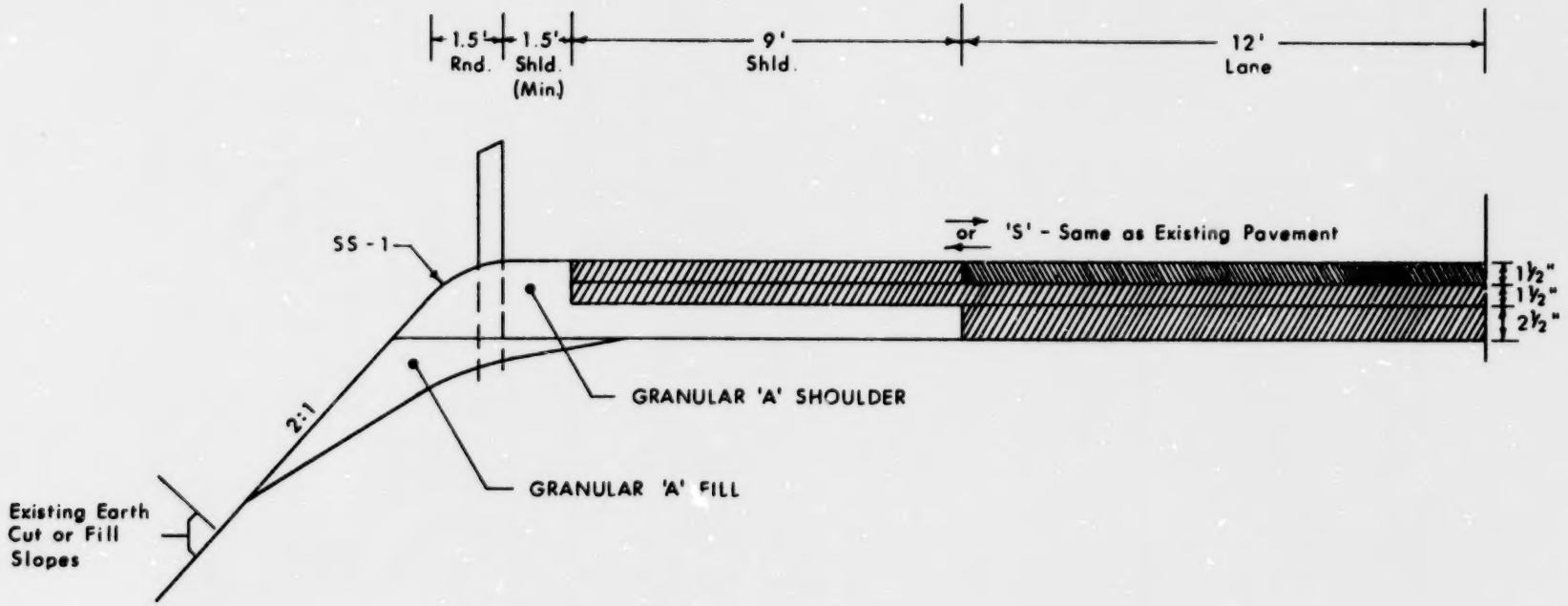
The vibratory rollers were observed to be causing undue displacement of the mat and creating hair checking at the very beginning, but with the addition of the pneumatic tire rollers and refined rolling practices, satisfactory results were obtained.

A continuing problem in the paving operation was due to oversize stones in the mix. Since the reclaim was only crushed to 40 mm, any stones below this size would end up in the final mix. The oversize stones near the 40 mm size would drag under the screed of the paver and tear the mat and smaller ones would pass under without dragging. Some days production was worse than others for oversize in the mix.

The paving crew would dig out the obvious stones and replace the void with mix from the augers before the breakdown rolling. After rolling, further stones would become evident in the mat due to the reduced cross-section. It was felt that these stones "carried" the rollers and contributed to non uniform compaction and reduced smoothness of the mat.

When placing the mix made with the RA-5.2 emulsion, the paver operator thought it came off the screed smoother and the breakdown rollerman commented that it was not as prone to displacement as the regular recycle mix. However, the men performing hand work, i.e. raking and shovelling, found the emulsion mix harder to work with. Other than for the oversize in the recycled mix, it was comparable to a regular virgin mix as far as the laying was concerned.

TYPICAL CROSS SECTION



APPENDIX I

DAILY SUMMARY OF CONDITIONS AT PLANT

CONT. No. 79-105

DATE 1980	WEATHER	TEMPERATURES °C								% MOISTURE						% A.C.			REMARKS
		AIR		VIRG. AGG.		RECLAIM		F. MIX		VIRG. AGG.		RECLAIM		F. MIX		RECLAIM	F. MIX		
		AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM		AM	PM	
June 16	Sunny	+5	+16		+27		+20	+136	+128	1.6	2.2	0.6	2.7	.1	.1	4.15	5.34	5.86	241 T.P.H.
17	Sunny	+16	+22	+18	+21	+19	+22	+125	+120	1.4	1.0	2.1	2.4	.1	.1	4.06		5.17	235 "
18	Cloudy & sl. rain	+13	+25	+23	+24	+22	+26	+118	+114	1.5	1.2	2.7	1.5	.2	.1	4.11	5.14	6.14	225 "
19	Cloudy & rain	+12	+20	+21		+26		+117		1.2		1.5		.1		4.67	6.00		218 "
20	Cloudy & rain	+9															Did not start due to rain.		
23	(am) cloudy (pm) sunny	+15	+29	+23	+25	+24	+26	+124	+123	3.0	2.1	3.0	1.3	.1	.1	4.51	5.92	5.31	260 T.P.H.
24	Sunny	+16	+32	+24	+27	+27	+29	+122	+116	3.7	2.4	1.2	1.3	.04	.1	4.34	5.99	5.67	250 "
25	Sunny	+16	+31	+25	+27	+28	+30	+124	+119	2.3	2.5	1.3	1.3	.04	.04	4.72	5.38	5.55	285 "
26	Cloudy	+18	+29	+30	+30	+32	+32	+120	+118	2.4	2.6	1.0	1.2	.04	.1	4.60	5.21	5.56	280 "
27	Sunny	+14	+22	+27		+30		+114		1.5		1.3		.1		4.31	5.52		320 "
July 2	Sunny	+16	+25	+19	+21	+18	+24	+121	+119	1.4	1.5	1.8	1.6	.3	.1	4.09	5.24	4.96	225 "
3	Sunny	+10	+26	+13	+15	+11	+20	+114	+117	1.5	1.6	1.5	1.4	.1	.1	4.20	5.22	5.15	300 "
4	Sunny	+13															Did not start due to no grade.		
7	Overcast Sunny Pe	+14	+28														6.29	5.55	
8	Cloudy	+18		+14		+10				2.1		1.5					Did not start due to rain.		
9	Cloudy	+14	+31	+15	+15	+14	+15	+117	+145	1.4	1.4	1.5	1.5	.1	.1	4.36	5.17	5.39	340 T.P.H.
10	Sunny	+10	+30	+16	+17	+14	+16	+121	+125	1.3	1.4	1.6	1.5	.1	.1		5.64	5.58	315 "
11	Sunny	+14		+11		+13		+135									5.89		
14	Cloudy	+14	+31		+13		+16		+120		2.2		1.4		.1	4.28	5.45	5.63	310 "
15	Cloudy & Drizzles	+20		+16	+19	+17	+18		+136	1.8	2.2	1.3	1.8		.1	4.89		6.30	315 "

DAILY SUMMARY OF CONDITIONS AT PLANT

CONT. No. 79-105

DATE 1980	WEATHER	TEMPERATURES °C								% MOISTURE						% A.C.			REMARKS
		AIR		VIRG. AGG.		RECLAIM		F. MIX		VIRG. AGG.		RECLAIM		F. MIX		RECLAIM	F. MIX		
		AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM		AM	PM	
July 16	Overcast	+19	+28	+16	+18	+18	+18	+118	+115	1.9	2.0	1.3	1.5	.1	.1	4.37	5.90	5.33	300 T.P.H.
17	Overcast	+18	+27	+16	+16	+18	+18	+117	+118	1.7	1.8	1.1	1.6	.1	.1	5.03		5.57	275 "
22	Overcast	+17	+27		+11		+16		+117		2.3		1.6		.1	4.39		5.08	290 "
23	Sunny w/ cloudy pr.	+18	+29	+13	+13	+18	+16	+125	+120	2.7	2.7	1.5	1.6	.1	.1	4.99	5.41	5.73	300 "
24	Sunny	+16	+30	+14	+14	+16	+16	+134	+132	2.8	2.7	1.5	1.3	.1	.1	5.05	5.91	5.54	250 "
25	Sunny	+15		+15		+15		+131		2.6		1.0		.1		5.13	5.99		290 "
28	Rain																		
29	Overcast	+16	+29	+16	+14	+16	+15	+121	+124	3.9	4.4	2.5	1.9	.1	.1	5.14	5.58	5.97	300 "
30	Sunny	+16	+27	+17	+17	+18	+18	+123	+125	3.8	3.7	1.8	1.6	.1	.1	5.17	5.59	5.11	300 "
31	Sunny	+15	+34	+16	+16	+17	+17	+122	+120	1.5	1.5	1.2	1.4	.1	.1	4.58	4.80	5.77	290 "
Aug. 1	Overcast	+17		+18		+17		+125		1.5		1.1		.1			5.16		310 "
	n	30	23	24	21	24	21	23	21	24	21	24	21	22	21	23	23	22	
	$\bar{X}$	14.8	27.3	18.2	19.0	19.1	20.4	123.2	122.4	2.10	2.16	1.54	1.59	0.11	0.10	4.57	5.55	5.54	
	σ	3.21	4.18	4.86	5.60	5.90	5.33	6.37	7.57	0.83	0.81	0.56	0.36	0.05	0.01	0.37	0.38	0.34	

BITUMINOUS INVESTIGATION

Cont. 79-105

LOCATION Hwy. 69; Parry Sound DATE 80-11-12

SAMPLE NUMBER	EXTRACTION			ABSON		DATE	REMARKS	STATION
	% RET. (4.75 mm)	% P. 75 um	% A. C.	PEN.	VISC.	1980		
-	36.0	4.8	4.69	35	760	80-06-12	Reclaim from cold feed.	
1	29.2	5.6	3.81	43	502	80-06-16	"	
2	30.0	5.2	4.30	39	691	80-06-17	"	
3	29.9	5.9	4.39	37	735	80-06-23	"	
4	31.9	6.0	4.47	35	665	80-06-24	"	
5	29.3	5.9	4.60	38	600	80-06-25	"	
6	29.2	5.6	3.80	39	577	80-06-26	"	
7	31.9	5.4	4.23	37	595	80-06-27	"	
8	31.0	5.1	3.96	49	566	80-07-02	"	
9	36.6	5.0	4.48	33	706	80-07-03	"	
10	27.6	5.4	4.19	26	1050	80-07-09	"	
11	29.9	5.2	4.38	29	962	80-07-10	"	
12	31.4	4.8	4.91	31	820	80-07-11	"	
13	33.6	4.7	4.53	32	733	80-07-14	"	
14	37.8	4.1	4.42	30	859	80-07-15	"	
15	36.8	5.2	4.65	30	927	80-07-16	"	
16	33.1	5.2	4.93	28	1003	80-07-17	"	
17	32.0	4.7	4.83	32	756	80-07-22	"	
18				27	964	80-07-23	"	
19				31	843	80-07-24	"	
20				34	787	80-07-25	"	
21				27	1111	80-07-29	"	
22				27	1062	80-07-30	"	
23				31	749	80-07-31	"	
24				31	794	80-08-01	"	
$\bar{x}$	32.1	5.21	4.42	33.2	792.9			
σ	3.0	0.5	0.3	5.5	167.3			
n	18	18	18	25	25			

APPENDIX IV-1

Ministry of Transportation and Communications
Ontario

BITUMINOUS MIX DATA
(FIELD AND LABORATORY TEST RESULTS)

CONTRACT NO. 79-105 HWY. NO. 69 DISTRICT NO. HUNTSVILLE 11
LOCATION Foots Bay to Hays Corners
MIX DESIGN: 70% Reclaim: 30% f/8A Adding 2% 300-400 Pen A.C.
TO YIELD A 40:60, 5.0 MIX

NO.	MIX TYPE	DATE	A.C.(F)	S.A.(F)	A.C.(L)	S.A.(L)	VOIDS	FLOW	STAB.	V.M.A.	% PASS 200 IN SAND	B.S.G.	M.S.G.
1	Recycle	June 10/80	5.22	59.6	5.22	61.4	2.2	12.9	3085	15.2	8.8	2.484	2.541
2		"	5.55	68.4	5.24	66.6	2.7	11.7	2863	15.6	8.7	2.462	2.536
3		June 11/80	5.38	62.2	5.26	63.9	2.1	12.9	3227	15.2	9.0	2.481	2.533
4		"	5.87	65.2	5.37	66.9	1.9	12.2	3248	15.1	8.8	2.481	2.530
5		"	5.88	65.6	5.51	66.7	2.3	12.1	2860	15.9	8.9	2.470	2.527
6		June 12/80	6.40	73.1									
7		"	5.09	69.0	5.73	69.7	2.3	11.9	2887	16.3	8.4	2.452	2.511
8		June 13/80	5.72	62.6	5.46	63.9	2.3	12.8	2895	15.9	9.8	2.485	2.544
9		June 16/80	5.34	64.8	5.10	65.0	1.7	15.1	3149	14.5	9.9	2.503	2.545
10		"	5.86	64.7									
11		June 17/80	5.17	63.6	4.97	64.0	2.6	12.5	3616	14.9	9.5	2.475	2.540
12		June 18/80	5.14	65.3	4.86	64.3	2.7	11.0	3942	14.8	9.7	2.480	2.548
13		"	6.14	70.4									
14		June 19/80	6.00	67.9	4.86	60.7	2.5	12.5	3763	14.5	9.4	2.475	2.539
15		June 23/80	5.92	65.7	5.19	63.2	1.7	13.9	3475	14.7	9.7	2.499	2.543
16		"	5.31	49.1									
17		June 24/80	5.99	65.8	5.21	65.0	2.3	12.9	3278	15.3	9.9	2.491	2.549
18		"	5.67	61.8									
19*		June 25/80	5.38	62.5	5.44	6.45	2.3	13.5	3325	15.8	-	2.486	2.544
20		"	5.55	61.8	5.44	63.0	2.3	13.7	3640	15.8	-	2.481	2.539
21		June 26/80	5.21	65.3	5.23	65.8	2.8	10.9	3663	15.7		2.471	2.541
22		"	5.56	66.9									
23		June 27/80	5.52	64.2	5.03	62.8	2.4	14.4	3474	14.8		2.474	2.536
24		July 2/80	5.24	65.4	5.08	63.0	2.4	12.8	2799	15.0		2.483	2.545
25		"	4.96	60.8									
26		July 3/80	5.22	64.3	5.28	63.8	2.1	13.8	3425	15.2		2.484	2.537
27		"	5.15	59.7									
28		July 7/80	6.29	65.4	5.69	65.7	2.2	17.0	3311	16.2	9.3	2.463	2.518
29		"	5.55	59.8									
30		July 9/80	5.17	62.6	4.97	64.5	3.0	12.8	3493	15.2	9.8	2.464	2.540
31		"	5.39	64.9									
32		July 10/80	5.64	62.5	5.14	61.4	2.4	13.7	3553	15.1	9.4	2.479	2.540
33		"	5.58	64.3									
34		July 11/80	5.89	64.8	5.21	63.8	2.4	15.3	3551	15.3	9.7	2.469	2.531
35		July 14/80	5.45	56.6			2.2	17.3	3172			2.468	2.524
36		July 14/80	5.63	61.3									
37		July 15/80	6.30	65.4									
38		July 16/80	5.90	63.1			2.2	15.4	3165			2.475	2.531
39		"	5.33	64.3									
40		July 17/80	5.57	62.5			2.4	17.3	3134			2.458	2.519
41		July 18/80	5.42	63.2	5.45	62.8	2.0	17.6	3030	15.4	9.2	2.464	2.515
42*		July 21/80	5.59	55.4	5.19	64.5	2.3	14.6	3160	15.1	9.8	2.464	2.521
43		July 22/80	5.08	61.2									
44		July 23/80	5.41	58.6									

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APPENDIX IV-2

Ministry of Transportation and Communications
Ontario

BITUMINOUS MIX DATA
(FIELD AND LABORATORY TEST RESULTS)

CONTRACT NO. 79-105 HWY. NO. 69 DISTRICT NO. HUNTSVILLE 11
LOCATION Foots Bay to Hays Corners
MIX DESIGN: 70% Reclaim: 30% 5/8A Adding 2% 300-400 Pen A.C.
TO YIELD A 40:60, 5.0 MIX

NO.	MIX TYPE	DATE	A.C.(F)	SA.(F)	A.C.(L)	SA.(L)	VOIDS	FLOW	STAB.	V.M.A.	% PASS 200 IN SAND	B.S.G.	M.S.G.
45		July 23/80	5.73	60.6	5.32	60.5	2.4	13.1	2992	15.4	8.7	2.453	2.513
46		July 24/80	5.91	62.2	5.45	59.5	1.9	13.3	3158	15.4	9.7	2.473	2.521
47		"	5.54	59.9									
48		July 25/80	5.96	61.3	5.44	62.2	2.1	16.0	3016	15.6	9.9	2.486	2.539
49		July 29/80	5.58	59.8	5.38	61.5	1.6	17.3	3307	14.9	9.8	2.477	2.518
50		"	5.97	61.3									
51		July 30/80	5.59	59.1	4.91	60.8	2.0	16.1	4014	14.2	9.7	2.484	2.534
52		"	5.11	56.7									
53		July 31/80	4.80	60.6									
54		"	5.77	60.9	4.92	62.2	2.3	14.3	3741	15.6	9.4	2.491	2.549
55		Aug 1/80	5.16	61.4	5.00	65.3	2.5	13.8	4113	14.9	9.5	2.487	2.552
56		Aug 5/80	5.77	63.2	5.07	61.2	2.2	14.6	3525	14.8	10.0	2.479	2.536
57*		Aug 6/80	5.36	67.3	5.23	70.9	3.9	10.8	3275	16.7	9.1	2.438	2.538
58*		"	5.49	62.1	5.40	65.9	2.3	12.4	3285	15.7	9.2	2.473	2.531
59		Aug 7/80	5.55	62.2	5.30	63.8	2.1	12.5	3349	15.7	8.8	2.479	2.532
60		"	5.99	66.3	5.52	55.2	2.6	12.5	2907	16.2	9.1	2.462	2.528
61		Aug 8/80	5.38	61.0	5.02	63.0	2.7	14.8	3553	14.0	14.2	2.485	2.554
62		Aug 11/80	5.55	63.0	5.04	63.1	2.5	11.3	2992	15.0	10.1	2.485	2.549
63		Aug 12/80	5.57	61.4									
64		Aug 21/80	5.68	64.2	5.43	62.8	2.4	12.0	2898	15.8	9.3	2.467	2.527
65		"	5.10	63.5									
66		Aug 25/80	5.53	66.5	5.27	63.8	2.9	12.5	2742	15.9	9.2	2.458	2.532
67		"	5.29	66.5									
68		Aug 26/80	5.31	66.9	5.18	64.6	3.1	11.0	3106	15.9	9.2	2.460	2.540
69		"	5.10	61.6									
70		Aug 27/80	5.20	61.5	5.24	63.1	2.2	11.6	3215	15.2	9.6	2.481	2.537
71		Sept 4/80	5.06	61.6									
72		Sept 11/80	5.02	66.3	5.00	63.0	2.7	12.2	3533	15.1	9.8	2.476	2.545
73		Sept 18/80	5.34	66.4	5.17	66.0	2.6	11.2	3446	15.4	9.7	2.473	2.540
74		"	5.41	65.8									
		$\bar{X}$	5.52	63.1	5.23	63.9	2.4	13.5	3316	15.3	9.5	2.475	2.535
		σ	0.34	3.53	0.21	2.24	0.39	1.86	322	0.55	0.88	0.01	0.01
		n	74	74	45	45	48	48	48	45	39	48	48

150-200 AC USED
* RA-5.2 EMULSION USED

OBM1286 4-77

APPENDIX IV-3

Ministry of Transportation and Communications
Ontario

BITUMINOUS MIX DATA

(MOBILE LABORATORY TEST RESULTS)

CONTRACT NO. 79-105 HWY. NO. 69 DISTRICT NO. 11 HUNTSVILLE
LOCATION FOOTS BAY TO HAYS CORNER

MIX DESIGN: 70% Reclaim: 30% 5/8A adding 2% 300-400 Pen. A.C.
TO YIELD A 40:60, 5.0 MIX

NO.	MIX TYPE	DATE		% COMP.	A.C. (%)	S.A. (%)	VOIDS	FLOW	STAB.	V.M.A.	% PASS 200 IN SAND	B.S.G.	M.S.G.
1	recycle	June 10/80			5.82	62.5	2.1	11.3	3050	15.5		2.468	2.520
2		June 11/80		97.0	5.80	68.1	2.5	10.0	2938	16.8		2.469	2.534
3		"			5.63	61.6	2.7	7.4	1800	16.4		2.441	2.508
4		June 12/80			5.78	65.4	2.7	9.4	2313	16.8		2.440	2.509
5		"			5.84	65.9	2.7	10.5	2600	17.0	6.5	2.455	2.523
6		June 16/80		97.8	5.41	62.6	2.2	10.9	3068	15.6	6.9	2.471	2.528
7		June 17/80			5.45	64.6	2.5	10.1	3.75	15.9	7.4	2.456	2.520
8		"			5.13	61.9	2.0	12.0	3914	15.2	7.6	2.477	2.528
9		June 18/80			5.01	61.2	2.6	11.3	3471	15.0	8.3	2.479	2.546
10		"			5.24	62.4	2.5	10.4	3414	15.4	6.9	2.471	2.535
11		"			5.23	62.7	1.8	10.6	3068	14.8	7.7	2.480	2.525
			$\bar{X}$	97.4	5.50	63.5	2.4	10.4	2937	15.9	7.3	2.464	2.525
			σ		0.29	2.16	0.31	1.21	513	0.79	0.61	0.01	0.01
			N	2	11	11	11	11	11	11	7	11	11
1		July 16/80		96.0	5.92	61.0	1.8	17.6	3588	16.5	8.2	2.476	2.522
2		"		94.1	5.42	61.6	1.6	16.0	3588	15.1	9.3	2.498	2.538
4		July 22/80			5.59	61.7	1.8	14.8	3353	15.6	12.0	2.475	2.521
5		July 23/80			6.40	64.1	1.5	12.5	2820	17.3	8.0	2.462	2.498
6		"			6.25	62.1	1.4	12.7	3033	16.9	11.4	2.472	2.506
7		"			6.17	61.2	1.4	13.0	3016	16.7	7.8	2.475	2.510
8		July 24/80		94.7	5.96	63.1	2.0	12.6	3120	16.8	7.8	2.480	2.531
9		"			5.88	62.6	2.3	10.9	3172	16.9	11.8	2.476	2.535
10		July 25/80			5.70	59.2	1.8	12.8	3380	16.0	12.0	2.495	2.539
11		July 29/80			6.34	60.8	1.5	14.5	3328	17.2	8.7	2.482	2.520
12		"			6.27	64.8	1.4	14.5	3224	16.9	7.7	2.475	2.511
13		"			5.36	62.0	2.4	13.2	3744	15.7	11.6	2.474	2.535
14		July 30/80			5.31	59.3	2.0	13.6	3640	15.2	8.4	2.480	2.531
15		"			5.49	58.7	2.1	13.4	3900	15.7	8.3	2.486	2.540
16		July 31/80		92.5	4.87	60.6	3.7	11.1	3928	15.7	8.3	2.474	2.571
17		"			5.48	61.9	2.0	11.9	3640	15.7	8.6	2.493	2.544
19		Aug 25/80		95.9	5.40	59.2	2.1	13.0	2938	15.5	7.9	2.483	2.537
20		Aug 26/80		93.5	5.20	64.9	2.1	12.7	3333	15.0	8.5	2.482	2.535
21		"		96.1	5.60	62.7	1.7	15.4	2982	15.6	7.8	2.481	2.524
22		Aug 27/80		94.9	5.14	62.0	1.7	12.1	3848	14.5	8.9	2.491	2.535
23		"			5.07	62.5	2.3	13.1	3188	14.8	13.1	2.473	2.530
			$\bar{X}$	94.7	5.66	61.7	1.9	13.4	3370	16.0	9.3	2.480	2.529
			σ		0.45	1.74	0.51	1.61	335	0.84	1.78	0.01	0.02
			n	8	21								

OBMT&S 4-77

APPENDIX IV-4

Ministry of Transportation and Communications
Ontario

BITUMINOUS MIX DATA

(FIELD TEST RESULTS)

CONTRACT NO. 79-105 HWY. NO. 69 DISTRICT NO. 11 HUNTSVILLE
LOCATION FOOTS BAY TO HAYS CORNERS

MIX DESIGN: 45:55 @ 5.3% 85-100

NO	MIX TYPE	DATE	A.C.(F)	S.A.(F)	A.C.(L)	S.A.(L)	VOIDS	FLOW	STAB.	V.M.A.	% PASS 200 IN SAND	B.S.G.	M.S.G.
1	HL-4	Aug 13/80	6.25	62.5									
2		"	6.02	58.9									
4		Aug 18/80	5.10	60.5									
5		"	5.41	58.9									
6		Aug 19/80	5.08	54.5									
7		"	5.40	59.5									
8		Aug 20/80	5.10	58.9									
9		"	5.36	60.7									
		-*	5.47	59.3									
		N	8	8									
		DESIGN CHANGE TO 45:55 @ 5.0% 85-100											
10	HL-4	Sept 3/80	5.16	65.8									
11		Sept 4/80	4.71	56.7									
12		"	4.81	56.0									
13		Sept 5/80	5.19	61.0									
14		Sept 8/80	4.94	60.4									
15		Sept 9/80	5.29	64.2									
16		Sept 10/80	4.92	57.3									
17			5.15	59.3									
18		Sept 15/80	4.97	53.9									
19		Sept 16/80	4.89	54.0									
20		Sept 19/80	4.88	52.9									
21		Sept 22/80	5.05	57.8									
22		Sept 23/80	4.69	57.6									
23		Sept 24/80	4.86	53.0									
24		"	5.09	53.5									
		$\bar{X}$	4.97	57.6									
		σ	0.18	3.99									
		n	15	15									

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BITUMINOUS INVESTIGATION

Cont. 79-105

LOCATION Hwy. 69; Parry Sound (Plate Samples) DATE 80-11-12

SAMPLE NUMBER	EXTRACTION			ABSON		DATE	REMARKS	STATION
	% RET. (4.75 mm)	% P. 75 µm	% A. C.	PEN.	VISC.	1980		
6	33.1	5.7	5.79	72	355		70:30 Recycle	409 ±
10	38.1	5.7	5.10	55	384	80-06-16	"	5' from c/l.
13	33.4	5.6	5.54	66	545	80-06-18	"	
16	37.4	5.7	5.22	65	387	80-06-23	"	
18	37.1	6.4	5.07	68	375	80-06-24		224 ±
-	38.2	6.2	4.96	60	412	80-06-25	"	328 + 50
22	37.3	6.2	4.80	83	331	80-06-26	"	194 ± N/B
-				66	368	80-06-27	"	
25	40.0	5.9	4.68	75	339	80-07-02	"	405 ± 18' from Centreline.
27	41.0	6.0	5.09	60	430	80-07-03	"	264 ± 5' from Centreline.
30				62	402	80-07-09	"	205 ± N/B
32				52	480	80-07-10	"	507 N/B
35				56	430	80-07-14	"	249 ± N/B
36				55	430	80-07-15	"	139 ± S/B
38				49	519	80-07-16	"	215 ± S/B
42	37.2	5.6	5.3	52	533	80-07-21	"	Emulsified Mix
43				63	408	80-07-22	"	82 ± N/B
44				60	415	80-07-23	"	480 ± N/B
-				73	347		"	165 + 100 S/B
47				59	411	80-07-24	"	418 ± N/B
50				46	534	80-07-29	"	417 + 00 S/B
52				47	548	80-07-30	"	244 + 00 S/B
53				54	403	80-07-31	"	631 ± S/B
$\bar{x}$	37.3	5.9	5.15	61.2	425.5			
σ	2.5	0.3	0.3	9.3	68.4			
n	10	10	10	23	23			

APPENDIX IV-6

BITUMINOUS INVESTIGATION

CONTRACT NO. 79-105 (RECYCLING)

LOCATION HWY. 69, FOOTES BAY TO PARRY SOUND (CORES FROM RECYCLED PAVEMENT)

DATE SAMPLED Aug. 19/80

SAMPLE NUMBER	EXTRACTION			ABSON		PAVEMENT SAMPLE			MARSHALL RE - COMPACTION				DEPTH IN INCHES (mm)	SURFACE TEXTURE	COMMENTS
	% RET.NO.4	% P.200	% A.C.	PEN.	VISC.	% VOIDS.	% COMP.	DIRT. PEN.	% VOIDS.	FLOW	STAB.	% V.M.A.			
Southbound Shoulder	35.1	6.9	4.85			5.0	98.2		3.3	11.7	4195	15.0	1-7/8" (50 mm)	Fairly tight & uniform.	Stn. 378+80 Binder
Southbound Shoulder	38.5	5.9	4.94			7.2	94.7		2.1	15.0	3984	14.1	2-1/8" (54 mm)	"	Stn. 287+50 Binder
Southbound Shoulder															1/2 km South of Horseshoe Lake Rd.
Top	35.6	6.1	5.13			8.6	93.8		2.5	12.6	4774	14.1	1-1/4" (34 mm)	"	Top - Emulsion as Virgin A.C.
Binder	44.0	5.8	4.74			10.1	92.2		2.5	14.2	4949	13.7	2" (5 mm)		Binder - Regular recycling.
Southbound Shoulder	36.0	6.0	5.38			8.0	94.2		2.3	15.9	4312	15.2	2-1/8" (55 mm)	"	Stn. 225+00 Binder
$\bar{X}$	37.8	6.1	5.01			7.8	94.6		2.5	13.9	4443	14.4			

APPENDIX III

CASE STUDY CONT. 80-202
CEDARAPIDS DRUM MIXER AT 70:30

CONTENTS

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RECYCLING CONTRACT 80-202; HWY. 17; WARREN TO HAGAR

GENERAL BACKGROUND

This section of highway is part of the Trans Canada northern route, which is the shortest link between the eastern and northwestern parts of the Province. This portion of Hwy. 17 was last rehabilitated in 1967 and was found in 1976 to be carrying 3700 A.A.D.T.

A 1975 passing lane study from North Bay to Sudbury identified the need for two passing lanes to be constructed in this section of the highway along with 130 mm more of hot mix paving on the existing lanes to meet design strengths.

The project was designed to be resurfaced with only 90 mm of hot mix instead of the 130 mm, due to monetary constraints along with padding quantities and construction of the two passing lanes.

With the inception of recycling and the dramatic increases in the cost of asphalt cement, it became economically viable to satisfy the strength requirements through recycling and so the design was altered to recycling.

THE EXISTING PAVEMENT

The highway cross-section consisted of 6.7 metre of pavement with 2.4 to 3.0 metre gravel shoulders. Thirty-six cores through the pavement determined asphalt thicknesses from 100 to 200 mm with an average of 150 mm. Granular 'A' below the pavement was found to range from 0 to 180 mm. The pavement was determined to have a good ride with extensive wheel track rutting and extensive longitudinal and transverse cracking.

NEW PAVEMENT DESIGN

The existing pavement was to be totally removed and pulverized and stockpiled for recycling. Recycled mix at 70:30, incorporating 16 mm type 'A' crushed gravel in the virgin fraction, was to be used for the two binder courses at 50 mm each. The 40 mm surface course was to be constructed using a virgin HL-4 mix. See Appendix I for typical cross-sections.

PAVEMENT RECLAIMING

The total 8.4 km of pavement on the contract was removed and pulverized prior to the start of recycling. The pavement was first ripped using a Cat D-8 dozer and loaded by front end loaders into trucks to be hauled to the gravel pit for crushing. Two removal operations were carried out simultaneously about 450 metres apart in adjacent lanes with a Cat 14E grader maintaining the grade between the operations for traffic.

A gravel pit was located a short distance off the job to the north of Warren and was the site of both the crushing and recycling operations. The crushing was performed using a Stamler feeder breaker for primary reduction and a Cedarapids 544 crushing plant for the final reduction to 40 mm. Production averaged 145 tonnes per hour. See Appendix II "Hours for Men and Equipment". Stones that were picked up along with the pavement were present in the final product also at minus 40 mm.

TESTING OF RECLAIM

In August of 1979, 36 cores were cut through the pavement in a pavement investigation for the project design. Six of these cores were tested by the Downsview Central Laboratory by extraction and Abson recovery. See Appendix III.

	A. C.	+ #4	Pass 200	Abson	
				Pen.	Visc.
Mean of six pavement cores	5.53	34.0	4.1	30	895

During the production of the crushed reclaim, end of belt samples were accumulated so that at the end of production a representative sample of the total reclaim pile was available for mix design purposes. This sample was shipped to the North Bay Regional Laboratory which determined that the reclaim contained 3.9% A.C.

The moisture content of the reclaim being fed to the asphalt plant was determined daily by the field laboratory in order to set the plant controls. The average moisture content of the reclaim was determined to be 2.6%. See Appendix IV "Daily Summary of Conditions at Plant".

During the production of recycled mix, daily samples of the reclaim were obtained from the cold feed of the plant. These samples were built up from many small portions obtained at random throughout the day. This sample was subsequently mixed and split down using a splitter box and one portion extracted in the field laboratory located at the plant and another portion shipped to the Downsview Central Laboratory for Abson recovery testing.

	A. C.	+ #4	Pass 200 in Sa.
Field Lab. Mean of 6	3.76	26.7	6.44

	ABSON	
	Pen.	Visc.
Downsview Lab. Mean of 12	24.2	971

The A.C. available from the reclaim is reduced around 32% from that available in the original pavement. The retained 4.75 mm sieve material is lowered by 21%. These two factors indicate an excessive amount of granular material (65 mm) was picked up with the pavement.

The drop in penetration from core samples at 30 to pulverized reclaim at 24 is surprising since this magnitude of penetration loss was not expected.

With an asphalt penetration of 24 in the old pavement and knowledge of the penetration of the virgin asphalt cement, a mathematical exercise may be carried out to predict the final in pavement penetration of the recycled mix. Certain basic assumptions, of course, have to be made in order to conduct this exercise, namely:

1. The old asphalt cement, since it now is in the 20s pen. range, will not harden any more.

2. The virgin asphalt cement will have a penetration drop of 40% of original.

Old A.C. @ Pen. 24 is 2.6/5 of mix (52%)
New A.C. @ Pen. 347 is 2.4/5 of mix (48%)
(.52 x 24) + .48 (347 x .60) = 112

Note calculations are based on actual values - if design values were used, the predicted pen. would be lower at 100.

MIX DESIGN

The North Bay Regional Laboratory designed the recycle mix using samples of the crushed reclaim and 16 mm type 'A' from the jobsite. A 70:30 mix with the addition of 1.9% 300/400 asphalt cement was selected. The design Marshall values of this mix were:

Voids	2.9
Flow	12.2
Stability	2840
Total A.C.	4.61

RECYCLE PRODUCTION

The Contractor produced the recycled mix in a Cedarapids 100-32 TMM drum mixer, retrofitted with an inner drum for recycling. The 20,000 tonnes of recycled mix were produced over three weeks in August at an average production rate of about 270 tonnes per hour.

The 16 mm 'A' virgin aggregate was fed to the inner drum from the plant's standard cold feed bins and the reclaim was fed into the outer drum from a separate cold feed bin equipped with a flat grizzly. The crushed reclaim became recemented in the stockpile and when fed into the reclaim bin required a labourer to break up chunks or throw them off the grizzly. The reclaim chute into the outer drum frequently clogged up forcing many minor shutdowns.

The recycled mix was produced with an average discharge temperature of 140°C and a mean moisture content of .05%. The virgin aggregates and reclaim feed to the plant contained 2.7% and 2.6% average moisture, respectively. The discharge from the drum was placed in a storage silo equipped with a batcher on top to control segregation.

It was noted that recycled mix as compared to a total virgin mix was more prone to freezing the silo discharge gates when not operated regularly.

TESTING OF RECYCLED MIX

A field laboratory was located in the pit with the asphalt plant to do the routine quality assurance testing and moisture determinations for plant control. In addition, a mobile laboratory was located just off the east end of the contract, for the first portion of the work, to check Marshall values of the recycled mix. Plate samples of mix from behind the paver were shipped to the Regional laboratory in North Bay for Marshall value determination. Plate samples were also shipped to the Downsview Central laboratory for Abson recovery testing. See Appendix V for individual laboratory results.

SUMMARY OF TEST RESULTS

	A. C.	SA.	VOIDS	FLOW	STAB.	V.M.A.	% PASS 200 IN SAND
Field Lab. Mean of 22	5.00	65.1					
Mobile Lab. Mean of 5	5.14	66.0	2.4	15.1	3946	15.2	7.4
Regional Lab. Mean of 10	4.70	66.3	3.5	13.6	3324	15.1	8.2

ABSON RECOVERIES	PEN.	VISC.
Mean of 12 Plate Samples	39	621

The data indicates that a higher A.C. content was achieved than had been designed, without the expected drop in voids. This should provide for a greater durability than could have been expected with 4.61% A.C. in the design.

The Abson recovered asphalt penetration is disturbingly low, far lower than predicted by mathematical calculation.

Overall mix variation was less with the recycled mix as compared to the virgin HL-4 surface mix placed on the contract. The standard deviation on the A.C. content was the same for both mixes at 0.3. The standard deviation on the sand/stone split was higher on the virgin mix at 5.3 than on the recycled mix at 3.3 based on the field laboratory results. See Appendix VI-1 and 5, Bituminous Mix Data.

PAVING

The recycled mix was used for the first two 50 mm lifts placed on the granular grade. The Contractor employed two Blaw Knox PF-180H pavers to spread the mix and two Dynapac dual drum vibratory rollers followed by two Bros SP 10,000 pneumatic-tired rollers for compaction. The mix was found to be comparable to a virgin mix and no problems with hand work were encountered. This same plant and crew previously worked on the recycling contract at Napanee where hand work proved difficult. The only problem encountered with the recycled mix was one of oversize stones in the mix from the reclaiming operation. The paving crew when observing a stone in the mat would remove it and shovel in fresh mix from the paver to restore the area.

APPENDIX I

GWP 816-75-01 HWY 17, FROM HAGAR TO WARREN 5.2 MI (8.4 km) DISTRICT 13 - NORTH BAY

FIGURE I
PASSING LANES

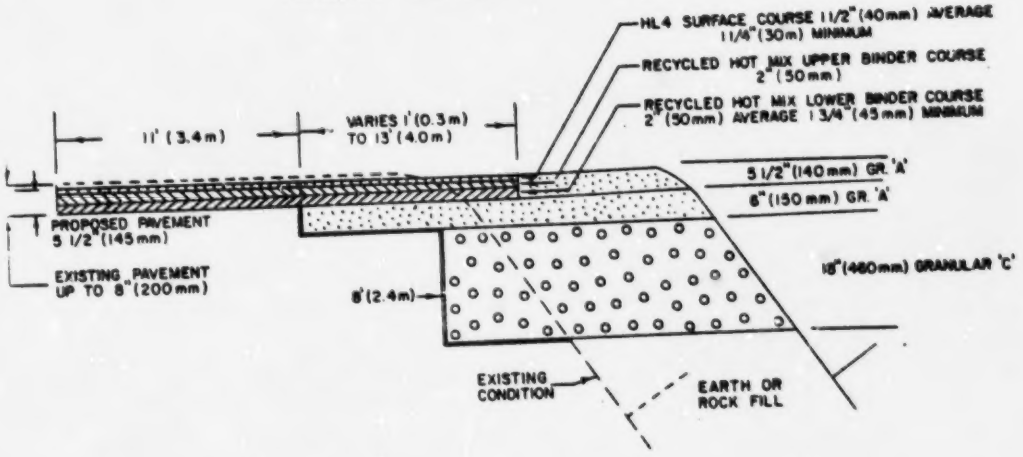
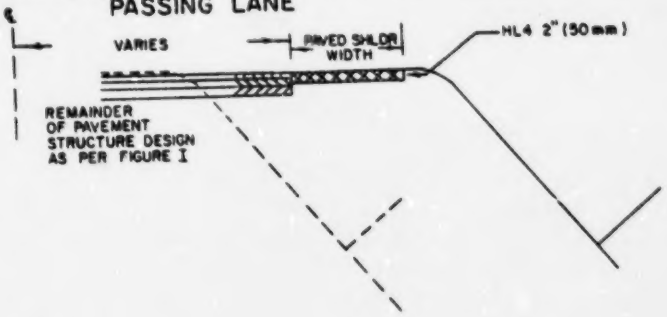


FIGURE II
PAVED SHOULDER FOR EROSION CONTROL
PASSING LANE



Ministry of Transportation and Communications
Ontario

Memorandum

To: Mr. A. Nozak,
Estimating Office,
Central Building, Downsview

From: Construction Office
Northern Region
North Bay

Attention:

Date: 80 11 24

Our File Ref.

In Reply to

Subject: The Hours for Men and Equipment Used on Contract 80-202 for the Pulverizing of Old Asphalt Pavement

The crushing operation started on June 11, 1980 and lasted until July 5, 1980. The Contractor took one day to set up and one day to tear down. The equipment used on this operation is as follows:

	Hrs. Worked	Hrs. Down
1 Impeller stambler, Model year 1980	184.5	55.5
1 Crusher Cedarapids, Model 544 Yr. 1969	184.5	9
Loader Terex Yr. 1980 4½ C.Y.	77.0	0
Loader Cat. 988, Yr. 1975 7½ C.Y.	39.0	0
Loader Trojan Yr. 1976 Series 2500 4.0 C.Y.	12.0	0
Loader Terex, Yr. 1980 4½ C.Y.	75.0	0
Dozer D6-C Cat. 1976	132.0	0
1 Foreman @ 240 Hrs.		
2 Operators @ 240 Hrs. Each		
3 Labourers @ 240 Hrs. Each		
A Stacker was also used	184.5	

The operation for picking up an overall average of 6½" of pavement throughout the length of the contract. The equipment and labour used on this operation is as follows:

1 Foreman	161 Hrs.	The hours given for man power is total for the entire length of the operation.
Labour	33.5 Hrs.	
Flagmen	623 Hrs.	

	Total Hours Worked
1 Cat. D8 Dozer & Ripper Yr. 1968 Series H.	161 Hrs.
Loader H90 Hough Yr. 1968 4 C.Y.	161 Hrs.
Loader Trojan, Yr. 1976 2500 Series 4 C.Y.	151 Hrs.
Grader Cat 14E (no further info. available)	157 Hrs.
The trucks used on this operation varied from 10 to 14 in number. All trucks were tandems and were paid hourly	1919 Hrs.

APPENDIX II-2

The total tons of pulverized material produced by these operations is 27,026.00 Tons.

The tons mentioned above were used on the contract. There was approximately 2000 to 3000 tons of material left in the stockpile bases that could not be used as it hardened to a thick mass and would have to have been re-crushed.

I trust this information is sufficient, if not I will gladly supply whatever else is required.

Original signed.

NOEL BISSONNETTE
PROJECT SUPERVISOR

NB/tt

APPENDIX III-1

BITUMINOUS INVESTIGATION

W.P. 816-75-01 (80-202)

LOCATION Northern Region DATE Feb. 18, 1980

SAMPLE NUMBER	EXTRACTION			ABSON		DEPTH IN mm	REMARKS	STATION km East
	% RET. (4.75 mm)	% P. 75 µm	% A. C.	PEN.	VISC.			
3	29.0	5.6	5.77	35	780	152	Original pavement cores.	0.50
7	32.3	5.7	5.77	23	1036	152		1.50
8	32.5	2.9	5.62	22	1066	133		1.75
28	35.1	3.3	5.46	35	813	165		6.75
32	37.7	3.4	5.13	26	909	146		7.75
33	37.1	3.8	5.41	41	767	178		8.00
$\bar{X}$	34.0	4.1	5.53	30	895			
n	6							

Ministry of Transportation and Communications
Ontario

BITUMINOUS MIX DATA
(FIELD TEST RESULTS)

CONTRACT NO. 80-202 HWY. NO. 17 DISTRICT NO. 17 - Sudbury
LOCATION Warren to Hagar

Reclaim from feed to asphalt plant.

CONTRACTOR

NO.	MIX TYPE	DATE 1980	A.C.(F)	S.A.(F)	A.C.(L)	S.A.(L)	VOIDS	FLOW	STAB.	V.M.A.	% PASS 200 IN SAND	B.S.G.	M.S.G.
	Reclaim	08 08	3.67	72.8							5.49		
		11	3.58	73.9							5.26		
		13	3.83	71.9							6.93		
		14	3.81	75.3							7.70		
		15	3.78	77.0							6.23		
		18	3.91	69.0							7.03		
		$\bar{X}$	3.76	73.3							5.4		
		n	6	6							6		

APPENDIX III-3

BITUMINOUS INVESTIGATION

Cont. 80-202

LOCATION Hwy. 17 DATE Nov. 26, 1980

SAMPLE NUMBER	EXTRACTION			ABSON		DEPTH IN mm	REMARKS	DATE
	% RET. (4.75 mm)	% P. 75 µm	% A. C.	PEN.	VISC.			
1B				23	1055		Reclaim from cold feed.	Aug. 8/80
2B				23	1005		" "	Aug. 11/80
4B				23	999		" "	Aug. 13/80
5B				26	893		" "	Aug. 14/80
6B				26	860		" "	Aug. 16/80
7B				22	961		" "	Aug. 18/80
8B				24	1002		" "	Aug. 19/80
9B				25	999		" "	Aug. 20/80
10B				23	1007		" "	Aug. 21/80
11B				26	961		" "	Aug. 22/80
12B				25	940		" "	Aug. 25/80
13B				24	970		" "	Aug. 26/80
			$\bar{x}$	24.2	971			
			σ	1.4	54			
			n	12	12			

APPENDIX IV

DAILY SUMMARY OF CONDITIONS AT PLANT

CONT. No. 80-202

DATE 1980	WEATHER	TEMPERATURES °C								% MOISTURE						% A.C.			REMARKS
		AIR		VIRG. AGG.		RECLAIM		F. MIX		VIRG. AGG.		RECLAIM		F. MIX		RECLAIM	F. MIX		
		AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM		AM	PM	
08 07	Overcast 26°C		26						132	1.8		2.0							300 TPH Mix looks good.
08 08	Rain	20	-	21	-	21	-	131	-	2.2	-	1.8				3.63	4.88		300 TPH Down in p.m.
08 11	Overcast	22	26	18	20	22	24	142	137	4.3	2.0	3.1	2.1			3.58	4.92	5.17	300 TPH
08 12	Overcast & Drizzle	19	22	17	20	20	22	-	149	-	4.6	-	3.4				5.22		Down in a.m. 300 TPH
08 13	Overcast Sunny Per.	15	20	15	20	16	18	135	131	2.7		2.8				3.83	5.46 4.71	5.09	Reclaim chute got clogged.
08 14	Overcast Sunny pm	19	25	18	20	18	19	-	-	-	4.2	-	3.7			3.81	-		Reclaim chute got clogged.
08 15	Sunny	19	-	19	-	21	-	141	-	3.3	-	3.1	-			3.78	5.33		250 TPH
08 18	Overcast	21	18	19	19	20	18	135	134	2.3	2.8	1.5	-			3.91	4.54		300 TPH
08 19	Sunny	24	29	20	25	22	20	142	145	2.5		3.1			.05		4.81	5.33	Reclaim chute got clogged.
08 20	Sunny	28	31	21	24	24	27	144	146	2.0		2.2		.07	.06		4.85	4.72	Reclaim chute got clogged.
08 21	Sunny	18	30	19	22	20	23	150	146	2.0	2.2	2.0	2.8		.07		4.83	4.91	275 TPH
08 22	Overcast	20	28	19	22	21	25	132	133	3.6		4.5					4.61	5.40	
08 25	Sunny	19	28	19	22	21	26	144	144	2.0		1.6					4.97	4.44	275 TPH
08 26	Rain, Overcast	29	29	21	24	24	25	140	145	2.9	2.6	2.8	1.8	.10	.04		5.04	5.04	Intermittent operation.
08 27	Rain		26																No production.
	$\bar{X}$	21	26	19	22	21	22	140	140	2.6	3.0	2.5	2.8	.04	.06	3.76	4.94	5.01	
	σ	3.9	3.9	1.7	2.0	2.2	3.3	5.8	6.8	0.8		0.9					0.3		
	n	13	13	13	11	13	11	11	11	12	6	12	5	4	4	6	13	8	

APPENDIX V-1

Ministry of Transportation and Communications
Ontario

BITUMINOUS MIX DATA
(FIELD TEST RESULTS)

CONTRACT NO. 80-202 HWY. NO. 17 DISTRICT NO. 17 - Sudbury
LOCATION Warren to Nagar

Mix Design - 70% Reclaim + 30% 5/8" 'A' and 1.9% 300/400 A.C.
CONTRACTOR to yield a 40:60 - 4.6 mix

NO	MIX TYPE	DATE 1980	A C (F)	SA (F)	AC (L)	SA (L)	VOIDS	FLOW	STAB.	V.M.A.	% PASS 200 IN SAND	B.S.G.	M.S.G.
	Recycle	08 07	4.88	69.1									
		08	5.26	63.5									
		11	4.92	65.4									
		11	5.17	67.8									
		12	5.22	66.4									
		13	5.46	69.1									
		13	4.71	67.2									
		13	5.09	67.8									
		15	5.33	62.3									
		18	4.54	62.8									
		19	4.81	69.3									
		19	5.30	62.7									
		20	4.85	66.4									
		20	4.72	59.8									
		21	4.83	56.3									
		21	4.91	63.4									
		22	5.40	67.4									
		25	4.97	69.3									
		25	4.44	63.3									
		26	5.04	64.7									
		26	5.04	64.2									
		29	5.12	63.7									
		$\bar{X}$	5.00	65.1									
		σ	0.3	3.3									
		n	22	22									

APPENDIX V-2

Ministry of Transportation and Communications
Ontario

BITUMINOUS MIX DATA
(MOBILE LABORATORY TEST RESULTS)

CONTRACT NO. 80-202 HWY. NO. 17 DISTRICT NO. 17 - Sudbury
LOCATION Warren to Hagar

Mix Design - 70% Reclaim + 30% 5/8" 'A' and 1.9% 300/400 pen. A.C.
CONTRACTOR to yield a 40:40 - 4.6 mix

NO	MIX TYPE	DATE	A C (F)	SA (F)	A.C (L)	SA (L)	VOIDS	FLOW	STAB.	V.M.A.	% PASS 200 IN SAND	B. S. G.	M. S. G.
	Recycle	Aug.8/80			5.09	64.3	2.2	14.3	3536	14.9	7.6	2.500	2.553
	"	" 8/80			5.34	66.9	2.3	15.7	3964	15.6	6.6	2.488	2.547
	"	" 11/80			5.31	66.2	2.3	14.2	3692	15.6	6.7	2.501	2.559
	"	" 11/80			5.04	66.4	2.6	17.1	4394	15.2	9.0	2.500	2.567
	"	" 12/80			4.94	66.2	2.5	14.3	4142	14.9	7.0	2.503	2.568
				$\bar{X}$	5.14	66.0	2.38	15.12	3945.6	15.24	7.38	2.498	2.5588
				σ	0.174	0.99	0.164	1.27	343.53	0.350	0.986	0.0059	0.0090
				n	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00

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Ministry of Transportation and Communications
Ontario

BITUMINOUS MIX DATA
(REGIONAL LABORATORY TEST RESULTS)

CONTRACT NO. 80-202 HWY. NO. 17 DISTRICT NO. 17 - Sudbury

LOCATION Warren to Hagar
Mix Design - 70% Reclaim + 30% 5/8" 'A' and 1.9% 300/400 Pen. A.C.
to yield a 40:40 - 4.6 mix

CONTRACTOR

NO.	MIX TYPE	DATE 1980	A.C.(F)	S.A.(F)	A.C.(L)	S.A.(L)	VOIDS	FLOW	STAB.	V.M.A.	% PASS 200 IN SAND	B.S.G.	M.S.G.
	Recycle	Aug. 11			4.93	-	3.1	14.9	3017	15.3	8.0	2.474	2.554
	"	" 12			5.20	65.0	2.3	14.7	3110	15.2	7.9	2.487	2.546
	"	" 13			4.67	69.8	3.5	12.9	3414	15.1	8.1	2.475	2.564
	"	" 18			4.23	63.7	5.0	14.3	3188	15.4	8.5	2.447	2.576
	"	" 19			4.53	68.7	3.7	13.1	3856	14.9	8.4	2.472	2.568
	"	" 20			4.67	68.0	3.6	13.1	2980	15.1	8.5	2.465	2.558
	"	" 21			4.77	61.2	3.1	13.8	3108	14.9	8.2	2.467	2.547
	"	" 22			4.96	67.1	2.9	14.0	3359	15.2	8.1	2.472	2.547
	"	" 25			4.33	66.5	4.7	12.8	3654	15.3	8.3	2.456	2.578
	"	" 26			-	-	2.6	12.7	3557	14.8	7.8	2.486	2.553
		$\bar{X}$			4.70	66.25	3.45	13.6	3324.3	15.12	8.18	2.470	2.559
		σ			0.309	2.829	0.85	0.818	294.21	0.199	0.244	0.0123	0.0119
		n			9	8	10	10	10	10	10	10	10

APPENDIX V-4

BITUMINOUS INVESTIGATION

80-202

LOCATION RECYCLED MIX (PLATE SAMPLES) DATE Nov. 26, 1980

SAMPLE NUMBER	EXTRACTION			ABSON		DEPTH IN mm	REMARKS	STATION
	% RET. (4.75 mm)	% P. 75 µm	% A. C.	PEN.	VISC.			
2A				32	671		DATE	
3A				45	543		Aug. 11/80	385 + 00 E/B
4A				36	649		Aug. 12/80	352 + 00 W/B
5A				42	584		Aug. 13/80	285 + 00 W/B
6A				42	686		Aug. 14/80	252 + 00 W/B
7A				50	470		Aug. 15/80	221 + 00 W/B
8A				38	582		Aug. 18/80	338 + 00 W/B
9A				41	581		Aug. 19/80	150 + 00 E/B
10A				40	581		Aug. 20/80	265 + 00 E/B
11A				45	517		Aug. 21/80	284 + 00 E/B
12A				33	721		Aug. 22/80	246 + 00 W/B
13A				27	872		Aug. 25/80	179 + 00 W/B
			$\bar{X}$	39	621		Aug. 26/80	193 + 00 E/B
			σ	6.4	107			
			n	12	12			

Ministry of Transportation and Communications
Ontario

BITUMINOUS MIX DATA
(FIELD TEST RESULTS)

CONTRACT NO. 80-202 HWY. NO. 17 DISTRICT NO. 17 - Sudbury
LOCATION Warren to Hagar

Mix Design - 45:55 with 4.9% 85/100 A.C.

CONTRACTOR

NO.	MIX TYPE	DATE 1980	A.C.(P)	S.A.(P)	A.C.(L)	S.A.(L)	VOIDS	FLOW	STAB.	V.M.A.	% PASS 200 IN SAND	B.S.G.	M.S.G.
	HL-4	08 29	4.88	48.8									
	"	29	5.38	58.9									
	"	09 02	5.57	64.1									
	"	02	5.24	64.8									
	"	02	5.49	67.0									
	"	02	5.29	53.7									
	"	03	5.36	52.7									
	"	03	4.91	55.9									
	"	04	5.03	58.6									
	"	04	4.81	55.5									
	"	05	4.75	51.9									
	"	05	5.07	56.5									
	"	06	4.76	51.2									
	"	08	4.66	51.2									
	"	08	4.77	60.4									
	"	09	4.67	56.1									
		$\bar{X}$	5.04	56.7									
		σ	0.3	5.3									
		n	16	16									

Ministry of Transportation and Communications
Ontario

BITUMINOUS MIX DATA
(REGIONAL LABORATORY TEST RESULTS)

CONTRACT NO. 80-202 HWY. NO. _____ DISTRICT NO. 17 - Sudbury
LOCATION Warren to Hagar

Mix Design - 45:55 with 4.9% 85/100 pen. A.C.

CONTRACTOR _____

NO.	MIX TYPE	DATE	A C (F)	SA (F)	A.C (L)	SA (L)	VOIDS	FLOW	STAB.	V.M.A.	% PASS 200 IN SAND	B. S. G.	M. S. G.
	HL-4	Sept. 5/80			4.78	51.2	4.3	13.1	2313	-	6.3	2.446	2.557
	"	" 2/80			5.16	61.9					6.0		
	"	" 2/80			4.99	55.9	4.4	11.8	2280	16.6	6.2	2.442	2.554
	"	Aug. 29/80			4.90	53.5	3.0	13.6	3016	15.1	6.0	2.465	2.540
				$\bar{X}$	4.958	55.63	3.90	12.83	2536	15.85	6.125	2.451	2.550
				σ	0.160	4.602	0.78	0.929	415.73	1.060	0.150	0.0122	0.009
				n	4.00	4.00	3.0	3.0	3.0	2.0	4.0	3.0	3.0

OSMTSS 4-77

APPENDIX IV

CASE STUDY CONT. 80-28
BARBER-GREENE CONTINUOUS MIX PLANT AT 50:50

CONTENTS

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RECYCLING CONTRACT 80-28; HWY, 15 and 29, SMITHSFALLS TO FRANKTOWN

GENERAL BACKGROUND

This project was designed as a widening and resurfacing contract of Highway 15 and 29 from Smiths Falls to Franktown. This 15.4 km section of highway is an arterial rout between the urban centres of Kingston, Arnprior and Ottawa. The existing highway was found to be carrying an average daily traffic of 3,550 vehicles in 1976 and this was expected to increase to 4,100 by 1985. The design of this project was reviewed in light of the Ministry's new policy of recycling rather than resurfacing and so the design was changed to recycling.

THE EXISTING PAVEMENT

The highway cross-section generally consisted of 6.1 m wide pavement with 1.8 m shoulders. The pavement depth averaged 127 mm over variable depths of gravel. Pavement was generally rated in fair condition with fair rideability and a few slightly rough and uneven sections. There was slight to moderate transverse and logitudinal cracking with slight to moderate wheel track rutting throughout.

NEW PAVEMENT DESIGN

The existing pavement was to be removed to a depth of 40 mm to a maximum of 50 mm except in areas designed for total removal such as culvert excavations and frost heave treatments. The reclaimed pavement was then to be recycled 50/50 with a 16 mm type crushed 'A' gravel. The recycled mix would then be used to widen the existing 6.1 m pavement to 7.3 m by placing 90 mm in a trench flush to and abutting the existing milled surface. A surface course of 40 mm of recycled mix would then be placed at 8.5 m width to provide for a 0.6 m paved shoulder on each side. Although the project was designed for 50/50 recycling, the contract was advertised as a 40/60 blend with an additional payment for each percentage point up to 50/50. This was due to some concern that 50/50 blends might not be possible in batch plants and thus allowed the contractor more latitude in his bidding.

PAVEMENT RECLAIMING

The contractor elected to remove the required 40 mm depth of pavement using two C.M.I. PR-225 cold milling machines with a cutter width of 1.4 m and a Sakai ER-160 cold milling machine with a cutter width of 1.9 m. Neither machine was capable of removing the width of one lane in a single pass and so two passes were required per lane. This caused problems with matching the cuts both longitudinally and transversely in that the resulting pavement had variable crossfall within a lane and sometimes a vertical step between passes. The first two days of production from both the C.M.I. and Sakai machines were stockpiled together but when it was discovered that the product from each machine was so different, a decision was made to stockpile the products separately. This, it was hoped, would minimize variability within the reclaim piles.

Where full depth pavement removal was required, the pavement was removed by backhoe or Gradall and trucked to the plant site and crushed by conventional crushing equipment to minus 40 mm. Stones picked up with the pavement removal presented themselves in the final product as oversize. The milling machines averaged 2,306 m^2 of removal each per day. Based on a depth of 40 mm, this is equivalent to 234 tonnes of reclaim. See Appendix I "Cold Planing Production Record".

The total reclaim underrun the tender by about 635 tonnes.

TESTING OF RECLAIM

The reclaimed material was tested as it was brought into the plant site for stockpiling by a field laboratory set up in the quarry. This laboratory checked the reclaim for moisture content, asphalt content, and gradation. The Sakai machine was found to generate 10% more Pass 4.75 mm than the C.M.I. planer and 2% more Pass 75 µm. During the production of the recycled mix, the moisture content of the reclaimed material was determined twice daily as it was being fed to the asphalt plant. Samples of reclaim were also obtained and shipped to the Downsview Central Laboratory for absorption recovery testing.

Summary of tests on reclaim going into stockpile:

Combined Sakai and C.M.I. Material

	% Moist	A.C.	+4.75	Pass 75 µm
Mean of 3 Tests	1.16	5.27	18.0	12.7
Product From Sakai Machine Only				
Mean of 10 Tests	1.44	5.44	20.0	10.2
Standard Deviation	0.77	0.17	3.41	2.01
Product From C.M.I. Machine Only				
Mean of 14 Tests	2.06	5.34	29.7	8.0
Standard Deviation	1.03	0.15	2.61	1.17
Product From Crusher				
Mean of 2 Tests	1.42	4.97	34.2	9.0

Summary of Tests on Reclaim Material Feed to Plant

% Moisture	+4.75	Pass 75 µm	Abson Pen.	Abson Visc.
$\bar{x}$ 2.42	25.2	8.5	29.8	859
σ 1.07	5.4	0.9	3.37	704
n 28	13	13	21	21

Having determined the penetration of the A.C. in the old pavement and knowing the penetration of the new virgin A.C., a mathematical prediction of the final penetration can be performed. Certain basic assumptions have to be made in order to conduct this exercise, namely:

1. The old asphalt cement, since it is now in the high 20 to low 30 range, will not harden any more.

2. The virgin asphalt will have a penetration drop of 40% of original.

   Old A.C. @ Pen. 30 is 2.7/4.7 of mix (57%)

   New A.C. @ Pen. 124* is 2/4.7 of mix (43%)

   (.57 x 30) + (.43(124 x .60) = 49.1

   Predicted in pavement A.C. Pen. is 49.

* Means of 8 samples.

MIX DESIGN

An existing stockpile of 16 mm type 'A' gravel at the plant site was found lacking in stone content and consistency as well as being high in Pass 75 µm. The contractor then screened the 16 mm 'A' into HL-4 stone and screenings and stockpiled these materials separately so that they could be blended back together in proper proportions in the cold feed of the asphalt plant. The testing of the reclaimed asphalt revealed a very low stone content and a high Pass 75 µm which would require the virgin fraction of the mix to be high in stone and low in fines in order to get a satisfactory mix.

The first mix attempted was:

40% CMI Reclaim

60% Virgin Aggregate - (70% stone, 30% screenings)

3.5% 150/200 Pen. A.C. to yield a total of 4.2%

This mix was found to have low V.M.A. and voids and so a natural blending sand was ordered and a new mix attempted using a 1:1 blend of screenings and blending sand. This mix was subject to the same problem as above and so the blend was increased to 2 blending sand to 1 screenings. The Marshall mix values were still not considered satisfactory and so a decision was made to use blending sand only and eliminate the screenings. There was no problem producing recycled mix with a 40:60 blend at 143°C and so the contractor asked for a mix design at a 50/50 blend of reclaim to virgin aggregate.

The mix design used for the milled reclaim was:

50% Reclaim

50% Virgin Aggregate (65% HL-4 stone and 35% natural sand)

2.0% 150/200 pen. A.C. to yield a total of 4.7%.

The mix design used for the crushed reclaim was:

50% Reclaim

50% Virgin Aggregate (50% HL-4 stone and 50% natural sand)

2.6% 150/200 pen. A.C. to yield a total of 4.8%.

RECYCLE PRODUCTION

The contractor employed a Barber-Greene K.B. 70 continuous mix plant equipped with a baghouse to produce the recycled mix between 80-06-20 and 80-08-01. This plant was modified by running a belt conveyor into the back of the pugmill from a single cold feed bin. The reclaim material was introduced into the pugmill at the same point as the virgin material so that both materials flowed under the asphalt cement spray bar. The plant was operated at a rate of 204 to 227 tonnes per hour. The first five days production of a 40:60 mix produced 1723 tonnes which were used in the pavement widenings and first binder in areas of total pavement removal. During this time, the mix design was varied by adding more and more blending sand to try and achieve higher V.M.A. and voids. This period of production determined that recycled mix temperatures up to 170°C were easily attainable with 2% moisture in the reclaim. At this point the contractor switched to a 50/50 recycle mix and produced it at an average temperature of 144°C with an average 2.4% moisture in the reclaim. The virgin aggregates were heated to an average of 270°C for this work but for two days when the moisture of the reclaim ran from 4 to 6%, the mix ratio had to be dropped to 45:55 in order to produce mix hot enough to eliminate the water. A virgin aggregate temperature of 277°C would only produce 50:50 mix at 120°C with water running out of the mix when using reclaim with 5.6% moisture.

When about two thirds through the recycling, it was found that the combined Sakai and C.M.I. reclaim that was the first stockpiled, now some 44 days old, had recemented in the pile and had to be reworked for a day with a loader before it could be fed through the plant. A labourer was still necessary to remove lumps going up the reclaim belt when this material was used. The final portion of the recycling (north end of contract) was performed using the crushed reclaim which contained stones up to 40 mm. The stones did not affect the recycle production but did cause problems at the road. The start-stop operation of the plant due to the low demand for mix at the road, (prior to starting on surface course paving) is thought to have contributed to mix fluctuations. This in spite of the operator trying only to shut down with his hot bins full so that any fines surge would run out the hot bin overflow.

TESTING OF RECYCLED MIX

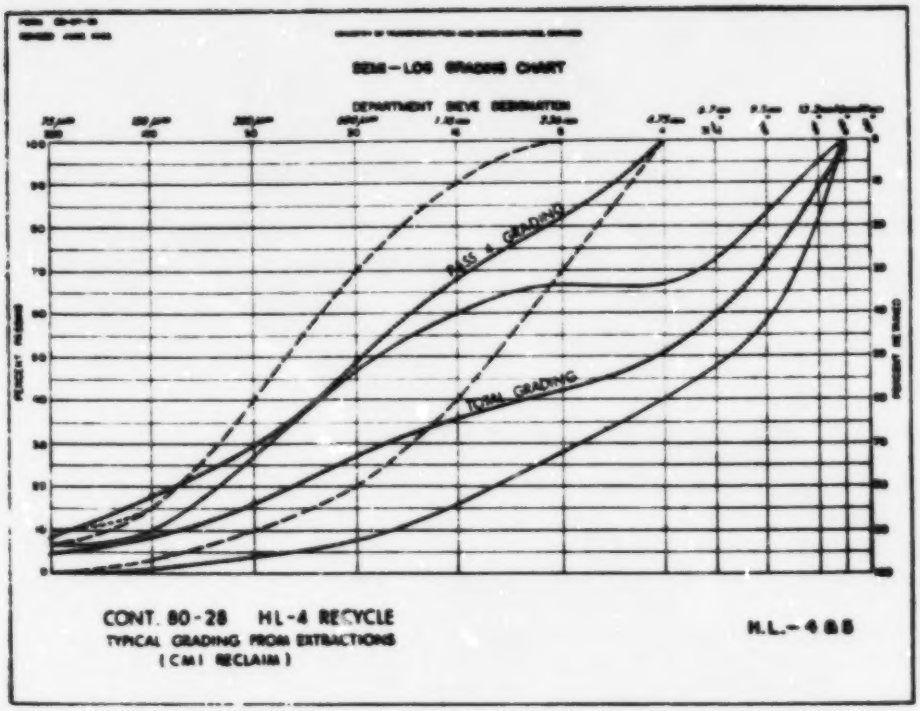
In addition to the field laboratory which performs the Routine Quality Assurance Testing, a mobile mix design laboratory was located at the plant site. This laboratory established Marshall Values of the mix during construction. Abson recovery testing for Penetration and Viscosity was performed by the Downsview Central Laboratory.

Daily records of the conditions at the plant were kept, noting weather, various temperatures and moisture contents of components and the final mix. See Appendix II. Plate samples obtained from behind the paver were used for the testing. Bituminous Mix data is contained in Appendix III.

SUMMARY OF FIELD AND MOBILE LAB RESULTS

	A.C.	SA.	VOIDS	FLOW	STAB	V.M.A.	% PASS 75 IN SAND
Recycling using C.M I. Reclaim							
Field lab/mean of 17	4.79	53.5					8.4
Mobile lab/mean of 20	4.94	54.3	1.9	13.7	3251	14.1	8.4
Recycle using Sakai/CMI Reclaim							
Field lab/mean of 6	4.53	54.1					9.5
Mobile lab/mean of 10	4.76	54.9	1.8	13.8	3412	13.6	10.1
Recycle using Sakai Reclaim							
Field lab/mean of 4	4.45	57.0					8.6
Mobile lab/mean of 4	4.58	54.8	2.6	12.4	3875	14.0	10.3
Recycle using crushed Reclaim							
Field lab/mean of 5	4.85	58.4					8.4

The low asphalt cement content set for the mix (4.7%) is much below the 5.3 to 5.5% that would normally be desired for a durable HL-4 mix with 55% pass #4. The low A.C. set was dictated by the Low voids due to the fine grading of the reclaim product. The following grading chart shows typical grading with the CMI reclaim being used in the recycle mix.



Comparing the uniformity of the recycled mix using the CMI reclaim (most samples) to virgin HL-4 Mixes produced by the same plant used on previous MTC contracts, we see that mix control is pretty good. Laboratory, rather than field inspectors results are compared. The standard deviation of the asphalt cement for the recycled mix is higher than three virgin mixes and the pass 4.75 mm standard deviation is less than two of the three.

CONT.	NO. SAMPLES	Standard Deviation	
		A.C.	Pass 4.75
77-68	29	0.25	3.50
77-83	19	0.27	3.06
78-64	31	0.26	2.13
80-28	20	0.29	2.98

It is fair to say that the A.C. variation is slightly higher in the recycled mix and that the gradation control is virtually the same as with virgin mixes.

The Downsview Central Laboratory performed 18 abson recoveries on plate samples taken from behind the paver with the following results: See Appendix IV.

	Pen.	Visc.
$\bar{x}$	45.9	545
σ	3.92	59.3

The mean in pavement penetration of 46 is slightly lower than the mathematical prediction of 49 as discussed previously under Testing of Reclaim.

PAVING

The pavement was placed using both Cedarapids and Barber-Greene spreaders used singly and compacted using static steel and pneumatic rollers. The quantity of recycled mix overrun the tender quantity by about 1088 tonnes. This overrun was the result of extra quantities used in padding to correct the geometrics of the road after milling. The mix was variously described as harsh, dead, stiff and sticky. The low voids and high stability of the mix could well lead to such descriptions. As may be inferred from the above descriptions, hand work was found more troublesome than with virgin mixes. The mix behind the paver had an open texture which was very resistant to closing up with the rubber tire roller. In spite of the extra padding quantities used, screed drag was still a problem due to crossfall variance from 2 to 4% on tangents. This screed drag gives the mat a non-homogenous appearance similar to segregation. Some segregation is also evident in the surface and close scrutiny would be required to differentiate between the two causes of non uniform texture. The north end of the contract near Franktown was paved using the reclaimed material crushed in the quarry. This portion of the road is badly blemished by oversize particles, some of which were dragged by the paver screed leaving a furrow behind. The paving crew picked out the larger stones as they showed up behind the paver and replaced them with mix from the augers but the quantity of oversize was beyond this treatment. The last two and one half days of production was a total virgin HL-4 mix due to running out of reclaimed material.

APPENDIX I

COLD PLANING PRODUCTION RECORD

	SAKAI #1348			CMI #105			CMI #122		
DATE	WORKING TIME (HRS.)	DOWN TIME (HRS.)	DAILY PRODUCTION (SQ. YDS.)	WORKING TIME (HRS.)	DOWN TIME (HRS.)	DAILY PRODUCTION (SQ. YDS.)	WORKING TIME (HRS.)	DOWN TIME (HRS.)	DAILY PRODUCTION (SQ. YDS.)
June 4	9.5	2.5	2600	10.0	2.0	2600			
5	10.5	1.5	3670	2.0	10.0	863			
6	7.5	1.5	2000	3.0	6.0	1161			
9	8.5	2.5	2766	0.5	11.0	267			
10	6.0	1.0	1935	8.0	2.5	2236			
11	9.5	3.0	3056	8.5	3.5	2600			
12	12.0	1.0	3673	2.5	10.5	683			
13	7.5	1.0	3974	0.0	8.5	000			
16	10.5	1.0	3961	10.5	1.0	5245	9.0	0.0	3433
17	11.5	1.0	3100	10.5	1.0	4611	11.5	1.0	4800
18	9.0	2.0	2500	9.5	1.0	3620	10.5	1.0	3907
19	11.0	1.0	-	10.0	0.0	-	8.0	1.0	-
20	12.0	0.0	443	12.0	0.0	622	12.0	0.0	340
23	11.5	1.0	3300	11.0	1.0	4700	11.5	1.0	6000
24	11.5	1.0	4062	9.0	3.0	2719	9.0	3.0	2719
25	7.5	1.0	2200	8.5	0.0	2934			
$\bar{X}$	9.72	1.38	2883	7.22	3.81	2324	10.2	1.0	3533
n	16	16	15	16	16	15	7	7	6
	87.5%	12.5%		65.4%	34.6%		90.2%	9.8%	

APPENDIX 1-2

Ministry of Transportation and Communications
Ontario

BITUMINOUS MIX DATA
(FIELD ~~AND LABORATORY~~ TEST RESULTS)

CONTRACT NO. 80-28 HWY. NO. 15 & 29 DISTRICT NO.
LOCATION SMITHS FALLS TO FRANKTOWN

= COMBINED PRODUCT OF SAKAI & CMI MACHINES =

CONTRACTOR DIBBLEE

NO	MIX TYPE	DATE	A C (F)	SA (F)	A C (L)	SA (L)	VOIDS	FLOW	STAB.	V M A	% PASS 200 IN SAND	B S G	MOISTURE
1	Reclaim	80 06 04	4.5	87.3							17.4		1.30
2	"	05	6.06	74.4							10.2		1.20
3	"	06	5.27	84.4							10.7		1.00
		$\bar{x}$	5.27	82.0							12.7		1.16

APPENDIX 1-3

Ministry of Transportation and Communications
Ontario

BITUMINOUS MIX DATA
(FIELD ~~AND LABORATORY~~ TEST RESULTS)

CONTRACT NO. 80-28 HWY. NO. 15 & 29 DISTRICT NO. _____
LOCATION SMITHS FALLS TO FRANKTOWN

= PRODUCT FROM SAMPLE MACHINE ONLY =

CONTRACTOR DIBBLEE

NO	MIX TYPE	DATE	A C (F)	SA (F)	AC (L)	SA (L)	VOIDS	FLOW	STAB	V M A	% PASS 200 IN SAND	B S G	MOISTURE
4	Premium	80 06 09	5·53	77·2							9·7		1·40
8	"	10	5·20	81·2							9·9		2·11
9	"	11	5·34	86·0							10·8		1·81
11	"	13	5·22	76·5							7·6		0·81
13	"	16	5·45	80·3							8·2		2·46
16	"	17	5·77	78·7							9·5		0·57
20	"	18	5·49	83·9							15·0		0·83
21	"	19	5·56	81·1							11·3		2·52
24	"	20	5·47	80·2							10·5		1·40
26	"	24	5·32	74·6							9·8		0·46
		$\bar{X}$	5·44	80·0							10·2		1·44
		σ	0·17	3·41							2·01		0·77
		n	10										

Ministry of Transportation and Communications
Ontario

BITUMINOUS MIX DATA
(FIELD ~~AND LABORATORY~~ TEST RESULTS)

CONTRACT NO. 80-28 HWY. NO. 15 & 29 DISTRICT NO. _____
LOCATION Smiths Falls To Perth Town

= Product From CMI Machines Only =

CONTRACTOR Dobbie

NO	MIX TYPE	DATE	A C (F)	SA (F)	A.C. (L)	SA (L)	VOIDS	FLOW	STAB.	V M A.	% PASS 200 IN SAND	B S G.	MOISTURE
5	Reclaim	80 06 09	5·17	69·9							7·3		1·40
6	"	10	5·39	70·7							7·2		1·30
7	"	10	5·28	73·9							8·8		1·45
10	"	11	5·53	71·0							7·2		1·84
12	"	13	5·44	69·3							6·9		0·72
14	"	16	5·45	65·3							6·1		0·59
15	"	17	5·50	72·6							9·1		3·96
17	"	17	5·43	68·4							9·7		2·58
18	"	18	5·42	68·0							7·1		1·45
19	"	18	5·14	67·3							8·7		2·35
22	"	19	5·20	72·8							9·2		2·55
23	"	19	5·00	74·2							9·6		3·68
25	"	20	5·46	72·0							8·2		3·15
27	"	24	5·32	69·1							6·9		1·86
		$\bar{x}$	5·34	70·3							8·0		2·06
		σ	0·15	2·61							1·17		1·03
		n	14										

APPENDIX 1-5

Ministry of Transportation and Communications
Ontario

BITUMINOUS MIX DATA
(FIELD ~~AND LABORATORY~~ TEST RESULTS)

CONTRACT NO. 80 - 28 HWY. NO. 15 & 29 DISTRICT NO. _____
LOCATION SMITHS FALLS TO FRANKTOWN

= PRODUCT OF CRUSHER IN QUARRY =

CONTRACTOR DIBBLEE

NO	MIX TYPE	DATE	A C (F)	SA (F)	A C (L)	SA (L)	VOIDS	FLOW	STAB.	V M A	% Pass 200 IN SAND	B S G	MOISTURE
28	Reclaim	80 07 02	4·63	62·8							9·6		2·02
29	"	03	5·30	68·7							8·3		0·81
		X	4·97	65·8							9·0		1·42

APPENDIX 1-6

Ministry of Transportation and Communications
Ontario

BITUMINOUS MIX DATA
(FIELD ~~AND LABORATORY~~ TEST RESULTS)

CONTRACT NO. 80-28 HWY. NO. 15 & 29 DISTRICT NO.
LOCATION
= 5/8 Type A From Existing Stockpile =
CONTRACTOR

NO	MIX TYPE	DATE	A C (F)	SA (F)	A C (L)	SA (L)	VOIDS	FLOW	STAB.	V.M.A.	% PASS 200 IN SAND	B S G	[illegible]
1	5/8 A	80 06 03		51·1							10·2		4·70
2	"	04		48·8							4·8		
3		05		63·2							12·8		
			x	54·4							9·3		

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DAILY SUMMARY OF CONDITIONS AT PLANT

CONT. No. 80-28

DATE 1980	WEATHER	TEMPERATURES °C								% MOISTURE						% A.C.			REMARKS
		AIR		VIRG. AGG.		RECLAIM		F. MIX		VIRG. AGG.		RECLAIM		F. MIX		RECLAIM	F. MIX		
		AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM		AM	PM	
06 23	Sunny		27°							3.61		1.17					4.32		40 Reclaim (CMI) 60 5/8" 'A'
06 24	Sunny		31°						169°	2.92	4.61	2.20	1.91				3.74	3.87	
06 25	Sunny		32°							2.53		1.99					4.06		40/60 with 1:1 Sand/Screenings
06 26	Rain																		No production.
06 27	Cool	17°		20°		17°		134°		4.86		0.92		.09			3.36		40/60 with 2:1 Sand/Screenings
07 02	Sunny	18°	28°	17°	22°	20°	29°		147°	18.6		2.49					4.92		50/50:Recycle Stone & Nat. Sa.
07 03	Sunny	20°	27°	18°	20°	22°	28°	130°	145°	2.41	1.57	1.62	2.13	.09			4.91	5.18	Slow production.
07 04	Sunny	22°		18°		26°		163°		1.90	3.10	1.51	1.74				4.57	4.60	
07 07	Sunny	28°	26°	23°	22°	28°	27°		123°	1.79	1.96	1.94	1.86				4.76	4.87	
07 08	Rain	15°	20°	17°	17°	19°	21°												No production.
07 09	Sunny	20°	24°	16°	17°	21°	26°	148°	148°	3.90		2.95					5.11	5.35	
07 10	Sunny	23°	27°	18°	19°	26°	27°	134°	149°	2.60	2.01	2.03	1.65				4.47	4.06	
07 11	Sunny	21°		17°		22°		147°		1.92	2.43	1.98	1.69				4.79	4.75	
07 14	Sunny	29°	31°	21°	21°	27°	26°	142°	140°	1.71		2.14					4.87	4.83	
07 15	Cloudy	23°	30°	20°	21°	26°	32°	146°	146°	1.91	2.02	2.74	2.12				4.74	4.70	Began surface course.
07 16	Cool, Cloudy	22°	21°	20°	18°	23°	20°	157°	148°	1.16		2.19					5.09	4.73	Switched to Sakai/CMI Reclaim
07 17	Overcast, Rain	26°	24°	23°	21°	23°	26°	170°		3.76		1.66					4.83	4.62	Plant shut down at 1:00 p.m.
07 18	Sunny, Warm	25°		17°		24°		148°		3.20	2.24	1.08	1.29				3.79	4.48	Production at 250 Ton/hr.
07 21	Rain in morning		27°		18°		25°												Plant shut down.
07 22	Rain in morning	23°	23°	19°	21°	22°	25°	131°	123°	3.95		2.11					4.30		Started using Sakai reclaim material.

DAILY SUMMARY OF CONDITIONS AT PLANT

CONT. No. 80-28

DATE 1980	WEATHER	TEMPERATURES °C								% MOISTURE						% A.C.			REMARKS
		AIR		VIRG. AGG.		RECLAIM		F. MIX		VIRG. AGG.		RECLAIM		F. MIX		RECLAIM	F. MIX		
		AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM		AM	PM	
07 23	Cool, Sunny	20°	22°	21°	21°	25°	23°	136°	136°	3.95	4.27	2.11	1.59				4.58	4.58	Finished CMI Reclaim Start Sakai in p.m.
07 24	Sunny, Warm day	24°	29°	18°	22°	24°	25°	148°	146°	2.75		4.03					4.46	4.47	
07 25	Sunny & Warm 31°C	28°		20°		25°		140°											
07 28	Cloudy & Warm 29°C		29°		22°		24°		140°		4.06		5.60				5.01	4.88	Using Crushed Reclaim @ 45:55
07 29	Rain 22°C	20°	26°	19°	24°	20°	22°												Plant shut down due to rain.
07 30	Sunny, Warm 24°C	20°	26°	18°	21°	23°	27°	136°	149°	4.39	4.01	4.03	4.99				4.61	4.88	45:55 due to high moisture.
07 31	Sunny & Warm 26°C	22°	30°	17°	23°	23°	27°	160° 149°	135°	3.44		3.30	3.04				4.88	5.23	Using crushed reclaim @ 50:50
		22	25	19	21	23	26	145.5	141.0	2.93	2.93	2.35	2.52				4.70	4.76	Mean
		3.5	3.2	2.0	2.0	2.5	2.9	11.4	8.9	1.02	1.11	.83	1.45				0.32	0.32	Standard Deviation
		20	18	20	18	20	18	18	14	20	11	17	11				18	16	No. Samples

APPENDIX II-2

APPENDIX III-1

Ministry of Transportation and Communications
Ontario

BITUMINOUS MIX DATA
(FIELD ~~AND LABORATORY~~ TEST RESULTS)

CONTRACT NO. 80-28 HWY. NO. 15/29 DISTRICT NO.
LOCATION SMITHS FALLS TO FRANKTOWN

CONTRACTOR DIBBLEE

NO	MIX TYPE	DATE	A C (P)	SA (P)	AC (L)	SA (L)	VOIDS	FLOW	STAB	V M A	% PASS 200 IN SAND	B S G	M S G
		DESIGN – 40:60 RECYCLE											
		VIRG. AGG. 70% STONE 30% SCREENINGS											
		ADD 3.5% 150-200 AC TO YIELD 4.2%											
1		80 06 23	4.32	55.4									
2		24	3.74	51.7							15.2		
3		24	3.87	53.6							15.5		
											9.7		
		$\bar{x}$	3.97	53.5							13.5		
		DESIGN – 40:60 RECYCLE											
		VIRG. AGG. 70% STONE 15% BL. SA. 15% SCREENINGS											
4		80 06 25	4.06	55.7							9.5		
		DESIGN – 40:60 RECYCLE											
		VIRG. AGG. 70% STONE 20% BL. SA. 10% SCREENINGS											
5		80 06 27	3.36	50.9							9.6		
		DESIGN – 50:50 RECYCLE											
		VIRG. AGG. 65% STONE 35% BLENDING SAND											
		ADD 2.0% 150-200 PEN. AC TO YIELD 4.7%											
6	CMI RECLAIM	80 07 02	4.92	56.4									
7		03	4.91	52.4							8.0		
8		03	5.18	56.3							6.1		
9		04	4.57	56.0							7.8		
10		04	4.60	57.1							8.8		
11		07	4.76	53.3							10.3		
12		07	4.87	56.7							7.7		
13		09	5.11	57.3							8.6		
14		09	5.35	55.6							7.5		
15		10	4.47	55.3							6.1		
											7.6		

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Ministry of Transportation and Communications
Ontario

BITUMINOUS MIX DATA

(FIELD ~~AND LABORATORY~~ TEST RESULTS)

CONTRACT NO. 80-28 HWY NO. 15/29 DISTRICT NO.
LOCATION SMITHS FALLS TO FRANKTOWN

CONTRACTOR DIBBLEE

NO	MIX TYPE	DATE	A C (P)	SA (P)	AC (L)	SA (L)	VOIDS	FLOW	STAB	V M A	% PASS 200 IN SAND	B S G	M S G
16	CMI RECLAIM	80 07 10	4.06	50.4							7.3		
17		11	4.79	48.2							9.5		
18		11	4.75	53.1							10.5		
19		14	4.87	50.4							10.9		
20		14	4.83	50.3							8.3		
21		15	4.74	50.9							9.2		
22		15	4.70	50.3							8.3		
		$\bar{x}$	4.79	52.5							8.4		
		σ	0.29	3.09							1.38		
		n	17										
23	SAKAI/CMI RECLAIM	80 07 16	5.09	56.5							8.8		
24		16	4.73	55.1							9.8		
25		17	4.51	52.1							10.2		
26		18	3.79	50.9							9.0		
27		18	4.48	54.6							9.3		
29		23	4.58	55.2							10.0		
		$\bar{x}$	4.53	54.1							9.5		
		σ	0.43	2.11							0.57		
		n	6										
28	SAKAI RECLAIM	80 07 22	4.30	58.1							9.6		
30		23	4.58	58.0							9.3		
31		24	4.46	60.8							6.1		
32		24	4.47	50.8							9.6		
		$\bar{x}$	4.45	57.0							8.6		
	DESIGN — 50:50 RECYCLE												
	VIRG. AGG. 50% STONE 50% BUSHY SAND.												
33	CRUSHED RECLAIM	80 07 28	5.01	59.2							9.6		
34		28	4.88	56.1							9.1		
35		30	4.61	57.0							7.2		
36		30	4.88	59.1							7.8		
37		31	4.88	60.7									
		$\bar{x}$	4.85	58.4							8.4		

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Ontario

BITUMINOUS MIX DATA
(~~FIELD AND~~ LABORATORY TEST RESULTS)

CONTRACT NO. 80-28 HWY NO. 15/29 DISTRICT NO. ____
LOCATION SMITHS FALLS TO FRANKTOWN

CONTRACTOR DIBBLEE

NO.	MIX TYPE	DATE	A C (F)	SA (F)	AC (L)	SA (L)	VOIDS	FLOW	STAB	V M A	% PASS 200 IN SAND	B S G	M S G
		DESIGN – 40:60 RECYCLE VIRG. AGG. 70% STONE 30% SCREENINGS ADD 3.5% 150+200 AC TO YIELD 4.2%											
		80 06 24			4.28	57.0	2.6	13.3	3495	13.3	11.4		
		24			4.47	62.2	2.2	16.8	3348	13.4	14.8		
		24			4.06	54.4	2.6	14.3	3890	12.8	12.1		
				℄	4.27	57.9	2.5	14.8	3578	13.2	12.8		
		DESIGN – 40:60 RECYCLE VIRG. AGG. 70% STONE 15% BL. SA. 15% SCR.											
		80 06 25			4.13	53.1	2.2	15.9	3230	12.6	11.5		
		DESIGN – 40:60 RECYCLE VIRG. AGG. 70% STONE 20% BL. SA. 10% SCR.											
		80 06 27			4.04	55.6	4.0	10.6	3820	13.9	7.0		
		DESIGN – 50:50 RECYCLE VIRG. AGG. 65% STONE 35% BLENDING SAND ADD 2.0% 150-200 AC TO YIELD 4.7%											
	CRI RECLAIM	80 07 02			5.09	57.3	1.9	12.8	3085	14.5	7.2		
		02			5.01	58.1	2.0	12.4	3240	14.4	6.9		
		03			4.97	55.8	2.2	12.5	3035	14.5	8.6		
		03			4.95	55.9	2.2	11.2	3550	14.4	7.0		
		03			5.08	54.7	1.9	14.3	2745	14.5	8.0		
		04			5.04	54.3	1.3	15.1	2855	13.8	9.4		
		04			5.03	54.6	1.9	12.7	3190	14.4	8.1		
		07			5.12	53.0	1.6	15.3	2875	14.3	8.5		
		07			5.03	53.9	1.5	14.8	3135	14.0	9.9		
		09			5.17	59.2	2.3	12.5	3125	15.0	6.9		
		09			5.13	58.4	1.9	12.8	3370	14.6	7.5		
		09			5.50	55.3	1.4	14.3	2600	15.0	8.1		
		10			4.64	54.7	2.4	12.9	3531	13.9	7.3		
		10			4.56	54.5	2.3	11.8	4032	13.7	8.3		
		10			4.18	48.8	3.5	10.9	4010	13.9	9.0		

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Ministry of Transportation and Communications
Ontario

BITUMINOUS MIX DATA
(~~FIELD AND~~ LABORATORY TEST RESULTS)

CONTRACT NO 80-28 HWY. NO 15/29 DISTRICT NO.
LOCATION SMITHS FALLS TO FRANKTOWN

CONTRACTOR DIBBLEE

NO	MIX TYPE	DATE	A C (P)	SA (P)	AC (L)	SA (L)	VOIDS	FLOW	STAB	V M A	% PASS 200 IN SAND	B S G	M S G
	CMI RECLAIM	80 07 11			4.76	51.0	1.8	14.4	2532	13.6	9.0		
		14			4.46	47.8	1.2	16.7	4045	12.4	8.8		
		14			4.92	50.8	1.2	15.3	3985	13.5	8.5		
		15			5.06	54.8	1.4	15.8	3130	14.0	10.4		
		15			5.12	53.9	1.3	16.0	3050	14.2	10.8		
				$\bar{x}$	4.94	54.3	1.9	13.7	3251	14.1	8.4		
				σ	0.29	2.98	0.55	1.68	478	0.58	1.13		
				n	20								
	SAKAI/CMI RECLAIM	80 07 16			5.01	55.1	1.7	15.3	3060	14.2	11.1		
		16			5.01	52.4	1.2	14.6	3060	13.7	10.3		
		16			5.19	54.2	1.0	15.8	2975	14.0	11.8		
		16			5.05	55.0	1.0	15.4	3155	13.6	9.1		
		17			4.83	55.3	1.4	13.2	3755	13.4	10.3		
		17			4.62	51.9	1.6	13.0	3252	13.1	10.8		
		18			4.03	56.1	3.0	11.1	4065	13.0	8.6		
		18			4.29	55.8	3.3	12.8	4050	13.9	9.5		
		18			5.02	58.9	1.3	14.0	3300	13.8	10.0		
		23			4.59	54.4	2.4	13.0	3445	13.8	9.7		
				$\bar{x}$	4.76	54.9	1.8	13.8	3412	13.6	10.1		
				σ	0.37	1.95	0.83	1.47	408	0.38	0.96		
				n	10								
	SAKAI RECLAIM	80 07 22			4.44	55.8	2.9	11.9	4285	13.9	10.6		
		23			4.60	55.2	2.4	12.7	3540	13.8	11.1		
		24			4.70	53.4	2.4	12.3	3730	14.1	9.4		
		24			4.58	54.9	2.7	12.9	3945	14.1	10.2		
				$\bar{x}$	4.58	54.8	2.6	12.4	3875	14.0	10.3		

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Cont. 80-28

LOCATION Smith Falls - Hwy. 15-29 DATE 80-11-04

SAMPLE NUMBER	EXTRACTION			ABSON			REMARKS	STATION
	% RET. (4.75 mm)	% P. 75 µm	% A. C.	PEN.	VISC.			
1B	33.0	7.2	5.66	30	852		Reclaim from cold feed.	
2B	22.9	9.1	5.33	30	847		"	
3B	21.5	9.3	5.55	29	890		"	
4B	26.4	8.1	5.72	25	1006		"	
5B	26.1	8 6.4	5.38	32	835		"	
6B	26.0	8.5	5.64	31	851		"	
7B	26.4	8.2	5.62	29	908		"	
8B	25.6	8.7	6.19	29	902		"	
9B	21.1	8.7	5.81	28	952		"	
10B	17.3	9.8	5.64	29	939		"	
11B	18.7	10.2	5.92	35	828		"	
12B				37	742		"	
13B				22	944		"	
14B				25	921		"	
15B				28	795		"	
16B				28	861		"	
17B	25.1	7.8	5.04	30	835		"	
18B				33	739		"	
19B	37.2	6.9	5.25	31	787		"	
20B				33	788		"	
21B				31	823		"	
$\bar{X}$	25.2	8.5	5.60	29.8	859		* Note: Samples not dried to a constant.	
σ	5.4	0.9	0.30	3.37	706			
n	13	13	13	21	21			

BITUMINOUS INVESTIGATION

Cont. 80-28

LOCATION Smith Falls - Hwy. 15-29; Recycled HL-4 Plata Samples DATE 80-11-04

SAMPLE NUMBER	EXTRACTION			ABSON		DATE SAMPLED 1980	REMARKS	STATION
	% RET. (4.75 mm)	% P. 75 µm	% A. C.	PEN.	VISC.			
1A	32.9	6.6	5.50	36	727	06 27	40:60 Recycle	S/B
2A	38.2	5.2	5.18	51	509	07 02	50:50 Recycle (CNI)	S/B
3A	42.9	5.0	4.94	45	561	03	"	N/B
4A	45.6	5.7	4.69	46	546	04	"	N/B
5A	45.8	5.2	4.97	46	562	07	"	291+50 N/B
6A	43.0	5.2	4.84	42	605	09	"	424+50 N/B
7A	53.4	5.0	4.90	51	574	10	"	231+50 N/B
8A	47.7	5.1	4.92	44	557	11	"	427+50 S/B
9A	48.3	5.3	5.41	46	512	14	"	134+50 N/B
10A	43.9	6.0	5.32	44	560	15	"	130+00 S/B
11A	46.6	5.8	5.21	45	535	16	" (CNI/SARAI)	124+00 N/B
12A	48.8	5.0	4.43	44	540	17	"	191+00 N/B
13A	44.9	5.9	4.19	42	571	18	"	220+00 S/B
14A				45	529	22	" (SARAI)	277+00 N/B
15A				50	491	23	"	289+00 S/B
16A	48.2	5.3	4.36	48	514	24	"	402+00 N/B
17A			NO SAMPLE			25		
18A			"	"		28	45:55 Recycle (Crushed)	
19A			"	"		30	"	
20A				52	475	07 31	50:50 Recycle (Crushed)	120+00 S/B
21A	39.4	4.6	5.06	48	450	08 01	"	172+00 S/B
$\bar{X}$	43.9	5.39	4.93	45.9	545			
σ	4.38	0.51	0.34	3.92	59.3			
n	15	15	15	18	18			